Supplement to THE ELECTRIC JOURNAL *for January, 1912.*

THE
ELECTRIC JOURNAL

VOL. VIII

JANUARY-DECEMBER

1911

Publication Office:
MURDOCH-KERR BUILDING
PITTSBURGH, PA.

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1911

THE ELECTRIC JOURNAL

Vol. VIII JANUARY, 1911 No. 1

PROGRESS IN 1910

TO make a detailed record of the progress of the past year, even in the field of electrical and associated industries, would require a large volume. Without, however, attempting to produce a formal history of the events of the past year, THE ELECTRIC JOURNAL is fortunate in being able to present the views of a number of men dealing with such notable features or such tendencies in their respective lines as may be significant and prove of general interest. The men who are contributors are leaders or experts in their several departments and the names accompanying the articles will be recognized at once as placing this series upon an unusually high plane.

In the midst of a general progressive activity it is often difficult to recognize what things are of real importance and whether certain changes are merely temporary modifications or whether they indicate general tendencies. It is, therefore, of particular interest to have those who are most competent to judge of the real merits of new apparatus and new methods point out in an informal and simple manner what appear to them to be the things of greatest significance and value.

The list of contributions does not cover the whole field, nor have the articles been edited to make them similar and symmetrical. Each writer treats his subject in his own way, adding thereby to the interest which our readers will have in this notable survey of recent progress and present tendencies.

GENERAL VIEW OF THE ELECTRICAL INDUSTRY FROM THE COMMERCIAL STANDPOINT

L. A. OSBORNE

ANY review of the accomplishments in the electrical field naturally focuses attention upon the technical and engineering phases of the work. The technical advance in electrical science has been so striking and so wonderful, and has been accomplished in such a relatively short time, that it constitutes one

of the intellectual marvels of the age. The development of electrical thought and the introduction of electricity into everyday use has resulted in a great commercial development. Electricity has become one of the great economic factors in the world's work, and on the stock exchanges are listed literally hundreds of millions of securities which have for their underlying value the ultilization of electrical energy in some form.

The commercial aspect of business, in its broad application, involves the financial, as well as that which is more apparent in the everyday life of the community—the relation of buyer and seller. To those who regard the growth of the electrical industries as a matter largely of technical interest, it is often a surprise to learn of the complex commercial activities which are related to the industry and through whose influence it is largely due that electricity is today so common a commodity.

While the selling of electrical apparatus by the manufacturer has followed more or less well defined lines since the inception of the industry, these latter days have witnessed an unsual awakening to activity of those whose problem it is to sell electricity itself. This recent activity in promoting the sale of electricity has been brought about by the recognition on the part of the producer that for many years his business had in no wise been as well developed commercially as other lines of comparable importance, but had, like Topsy, "just growed".

It is characteristic of our modern life that huge sums are annually spent in an effort to create a demand, and it is often remarkable the extent to which a market can be created for an article or a commodity for which there was previously no especial demand. Electricity, however, is not one of those commodities for which, up to very recent times, it seemed necessary to create a demand. That the attempt to do so has resulted in splendid returns and led to an enormously increased use of electrical apparatus, is a matter of recent history.

The problems connected with the use, distribution and application of electricity are highly complex, so that the commercial campaign looking to the creation of a wider market for electricity has developed methods of business getting which are unique and based upon highly technical and scientific grounds. The free use which has been made of the modern methods of publicity is also characteristic of this campaign.

Collateral to this systematic effort to secure a more widely ex-

tended use of electricity, both for lighting and power purposes, a well defined tendency has developed among the producers of electricity to syndicate their business. Hundreds of plants, which a few years ago were operating as independent units, have in recent years been gathered together into groups which are operated by so-called "syndicates". Through these syndicates and operating companies, uniform and economical methods are established, purchased are grouped, standards are more closely followed, all to the end of systematizing and rendering more stable the industry of producing electricity. Great impetus has been given the increased use of electricity by this movement, as concerns, hitherto independently operated, have been enabled to benefit by the experience of others and business-getting methods have been adopted which have been found to be useful elsewhere; and all this has led to a further popularization of electricity.

On the side of the manufacturer, this modern tendency has been welcomed, and there has been the fullest degree of coöperation on his part in helping to create the demand. The business has been made more stable by the larger purchases of standard apparatus by these syndicate properties, which has enabled the manufacturer to produce the goods in greater quantities, and at a constant improvement in quality and reduction in cost. The creation of this demand has, on the other hand, brought to the manufacturer new problems in the sale and distribution of his goods, requiring, among other things, the maintenance of large stocks at various points available for ready and prompt distribution.

The problem of the manufacturer has changed markedly in recent years, and from a machinery business, as it was in the earlier days, where the selling problems were relatively simple, it has become, to a large extent, the problem of marketing standard commodities. This has increased the cost of marketing and distribution, which is in some measure offset by the fact that electrical commodities are sold on short time, and he is enabled to turn his capital over more often than in the old days, when he was selling principally machinery. So, while the profits per unit are less and the cost of distribution and sale more, the business is more stable, less subject to violent fluctuations, and bids fair, thanks to the ever-increasing use of electricity in industry, transportation and the household, to have an uninterrupted and satisfactory growth.

AN ENGINEERING VIEW OF THE ELECTRICAL INDUSTRY

CHAS. F. SCOTT

IN engineering, progress is the normal condition. In electrical activity there is a sort of five-year period which brings a one hundred percent increase. While our population has increased twenty percent or one-fifth in ten years, our electrical activities have approximately quadrupled. This increase is not merely in quantity, but in quality and in type as well. For example, in railway work not only are many more motors used for ordinary street cars, but these motors have undergone continual improvement in design.

Even after a score of years of development, a radical reconstruction has recently taken place through the introduction of the interpole motor. At the same time electrical designs for new kinds of work and larger sizes have been going forward. The Pennsylvania terminal electrification in New York City has resulted in the development of the largest electric locomotives yet constructed, which form a fundamental factor in a terminal enterprise so extensive that it is hard to realize what an innumerable number of large engineering plans and minute details are involved in its successful operation. The full story of the development and carrying out of the engineering ideas which enter into this great work, or even the story of the electrical and mechanical development of the locomotives and the auxiliary apparatus in the system between the steam turbine and the driving axle, would be the account, not of some brilliant invention, but of an engineering cooperation in which hundreds of ideas are made to contribute to one harmonious whole. The present state of electrical engineering is indicated, not so much by its large achievements, but by the fact that a successful result is regarded as a matter of course. Not only in railways, but in power stations, in power transmission, in steel mill operation, in the general application of motors to the industries, projects which transcend the possibilities of a few years ago are now realized without exciting more than passing comment. Progress is the normal condition.

In reviewing the past year, many examples of advance are noted:—In some cases new types of apparatus appear; in others, improvements in present types are found; in others, new applica-

tions are made. All, however, contribute the one general conclusion that there is a forward motion all along the line.

In the design of apparatus, there is found a general tendency toward simplicity, reliability and durability. The old-time criticism of the electrical designer that he was concerned with the excellence of his machine, primarily because it embodied proper theoretical principles, no longer applies, as he is giving increasing consideration to the performance of his machine in service, realizing that a high percentage of reliability is as important as a high percentage of efficiency.

Increasing attention is being given to the proper adaptation of electrical apparatus to the work to be performed. A motor is not merely to supply power, but it should be suited by its mechanical adaptation, its speed regulation, its automatic control, or other features, to perform its work better than is possible by any other method. This kind of engineering design not only produces electrical apparatus which is inherently better, but it secures an adaptation in operation which is equally essential to effective results.

Electricity stands for progress. In science, in industry, and in ordinary life it is the means of doing new things and of doing old things in a better way. Every new discovery, every improved method and every useful application of electricity lead to others. Hence, continual progress is a normal condition in the science and in the industry, which is the means of advancement in other fields.

The activity which is taking place in so many different branches of the electrical industry, the increase in the general public use for operating machinery, running cars and trains, for general lighting and power purposes, and for domestic heating, together with the increasing importance and efficiency of the central station for making and distributing electric power, are all really contributing to one end, namely, the electrical Utopia, where central stations with their connecting network of conductors will be the source of universal supply for light and heat and power for industrial and transportation and for domestic use. And a continuation of the present accelerating rate of progress may bring about that ideal state sooner than we expect.

The large amount of research and scientific work which electrical manufacturers generally are devoting to improvements in apparatus is, from one standpoint, a sad necessity, but from another, it insures progressive improvement and it means that electrical methods are preparing to take a larger and deeper part in the operations

of modern life. It is a common story that in industries and in uses, where electricity was ten or five years ago regarded as an experiment or a joke, it is now an established necessity. This has not come about by accident, but through the use of the right kind of apparatus in the right way.

A new era in illumination has come about, not merely because there are better lamps, but also because they are more intelligently used, and the value of good illumination is becoming better understood.

PRESENT TENDENCIES IN THE DESIGN OF ELECTRICAL MACHINES

B. G. LAMME

BROADLY speaking, the present tendency in the design of electrical machinery is toward the greatest possible output at the least expense in cost and performance. This is indicated by the use of better grades of magnetic material, the increasing use of high heat-resisting materials, such as mica, asbestos, etc., and by increase in speed wherever possible and by modification in performance characteristics, where this can be done without increased operating expense.

As to improved magnetic materials, the use of silicon steel has become rather general in transformers, in order to reduce the iron losses and thus permit increased ratings. However, due to the slightly poorer permeability of such steels, in general they do not represent any real gain in output when applied to generators and motors. In fact, what is wanted in such machinery is not a low loss steel, so much as one with a very high permeability; that is, with a high permeability at high inductions, such as 120 000 to 150 000 lines per square inch. A grade of steel, in both solid and sheet form, which would allow 20 to 25 percent higher induction with the same magneto-motive-force as in present material would revolutionize present constructions of electric machinery. Even a very few percent allows a considerable gain in the designs and the best permeabilities obtainable are now being used.

The output of electrical machinery can also be increased by the use of insulating materials with greater heat-resisting qualities. Mica and asbestos are the two materials which are in most general use, and these are being used more and more extensively in armature and field windings. Such materials are particularly effective

in apparatus which is subject to excessive overloads for a moderately short time, where the machine as a whole would not have time to overheat, although there may b high local heating in the windings.

A third method for increasing the output with a given amount of material is by means of higher speeds. In low speed machinery, an increase in speed will allow an increase in output practically in proportion to the speed. However, as very high speeds are attained, the constructive features become more difficult and more expensive, until finally a point is reached where any increase in output due to increase in speed is accompanied by a corresponding increase in cost. Therefore, the designer aims to keep somewhat below this, except in such classes of machinery as high speed turbo-generators, where the engine characteristics call for the highest speed possible.

The present tendency is toward the highest speeds consistent with desirable designs. Following this tendency, the speeds of synchronous converters, motor-generators, turbo-generators, water-wheel generators, etc., have been raised gradually to a point where the present designs, in many instances, represent the most economical machines, as regards cost and operation. However, improvements in the design and construction are continually being made, which may allow still further increase in speed, so that eventually much higher speeds than at present may become standard. However, in some cases the theoretical limit of speed already has been reached. For example, the smallest number of poles which can be used is two, which corresponds to 3 600 revolutions for 60 cycles and 1 500 revolutions for 25 cycles. For 60 cycles it is practicable to build alternating-current turbo-generators up to 5 000 k.v.a., maximum capacity, or possibly higher, with two poles; and for 25 cycles 1 500 revolution, two-pole generators can be built up to almost any capacity. It is evident, therefore, that wherever the alternating-current two-pole generator or motor is used, no further increase in speed can be expected.

In direct-current turbo-generators the limit of speed appears to depend upon the skill of the designer and manufacturer of the electrical part of the unit. For the present, speeds for such units are considerably lower than in alternating-current practice. The limit is found principally in the collection of the current and, therefore depends upon the commutator and brush holder design and operation. There are, at present, certain limits to the permissible

peripheral speed of commutators with carbon brushes, beyond which designers do not feel free to go. If higher limits eventually prove practicable, then the speeds of direct-current turbo-generators can be increased accordingly.

In motor-generators the tendency is toward the highest possible speeds consistent with good design. The introduction of interpoles has been of very great assistance in increasing the speeds, as formerly, in very high speed direct-current generators of large capacity, a limitation was encountered in the commutation. With this removed by the use of interpoles, the speeds have been increased until the limit of cost has now become involved. The problem has been complicated somewhat in this country by the use of two frequencies, namely, 25 and 60 cycles, and it has been the endeavor to select standard speeds which will be suitable for both frequencies.

In synchronous converters there has been considerable increase in speed in 60 cycle machines until at present these speeds are approaching very close to those of direct-current turbo-generators, especially in the case of 600 volt machines. Further increase in speed in 60 cycle converters probably will have to be accompanied by more or less radical departures in the design of such machines. In 25 cycle converters there is still room for increase in speed, especially in the higher voltage machines. When the ultimate limit in speed is reached it is possible that interpoles will be used to a considerable extent, especially in those machines which have a wide range in load or where the peaks are very high compared to the average load.

There are other conditions which also tend toward increased rating of electrical machinery, such as improved methods of ventilation, modification in the performance characteristics, etc. In the matter of ventilation there has been great development in the past few years. With a tendency toward higher speeds and greater outputs from a given volume of material, the ventilation problem becomes of greater importance, for the higher outputs are usually accompanied by somewhat increased losses. Where the volume of material remains practically the same, with losses increasing, it is evident that a corresponding improvement is required in the means for dissipating the heat represented by the losses. The problem of ventilation is, therefore, becoming one of utmost importance. Where the outputs have been increased enormously, as in high speed alternating-current turbo-generators, artificial cooling has come into very general use. In such machinery it is usual

practice to bring in the cooling air through conduits, this air being fed into the machine by means of powerful fans or blowers which usually form part of the machine itself.

In machines operating at lower speeds, artificial cooling, as a rule, has not been used to the same degree as in the alternating-current turbo-generators, although in some instances the machines have been semi-enclosed in order to direct the cooling air along certain channels or paths. Also, cooling fans or blowers are used to a certain extent at the present time on some types of small motors.

Increased output can be obtained in many instances by some sacrifice in the performance characteristics of the machines, such as regulation, efficiency, etc. With the great advances which have been made in the design of electrical machines in the past ten years, there has been relatively little improvement in their efficiency, although the combined efficiency of complete units, such as generator and prime mover, has shown great improvement. A considerable betterment in the efficiency of electrical machinery could have been made very readily, but it would have been, to a certain extent, at the expense of output or first cost. In consequence, when there is a tendency toward increased output with a given cost, the efficiency has suffered relatively; that is, it has not shown the same improvement as found in other characteristics.

In the matter of regulation there has been more or less change in alternating-current generator practice in the past few years. The present tendency is in the direction of reduced inherent regulations, especially in alternating-current turbo-generators and large alternators. Good inherent regulations is an expensive characteristic, and it is becoming recognized more and more that it is an unnecessary and even a disadvantageous characteristic in some alternating-current machinery. It is also becoming more generally known that automatic regulators, of the Tirrill type for example, can accomplish better results, even with alternators with poor inherent regulation than can be obtained without such a regulator with the best inherent regulation that can be furnished commercially. By some sacrifice in the inherent regulation of turbo-generators, for instance, a relatively great gain in capacity becomes possible. Also, in many instances, by a change in the regulation, an increased output can be obtained with little or no increase in losses, and in consequence, the efficiency also can be raised materially. In most cases, therefore, a large alternator with very good inherent regulation represents very poor economy in cost and performance. It

is also becoming recognized that with varying inductive loads of relatively low power-factor the inherent regulation of the best possible alternator is relatively bad and that an automatic regulator is required if constant terminal voltage is necessary. While this tendency toward reduced inherent regulation in alternators of large capacity is quite marked, it has not yet been carried to the permissible limit, due principally to the fact that the engineering public is not yet educated to the realization of the price that is being paid for an assumed good inherent regulation, which is of no particular value to anyone.

The general tendencies in many classes of electrical machinery have been referred to briefly, but there are a few which have not yet been mentioned, such as railway apparatus, motors for general industrial service, commutator type alternating-current motors, etc.

In direct-current railway motors the whole tendency is toward the interpole type, even for the small ratings and for all voltages from 600 to 1 500. There is also some tendency toward reduction in weight, but if this is ever carried to its limit, it will naturally result in some sacrifices in mechanical as well as electrical excellence. The present direct-current railway motor is a very substantial piece of apparatus, and it is possible that, by trimming here and there, both in the mechanical and electrical parts, a considerably lighter type will be evolved.

In alternating-current railway motor work, the tendency in European practice is entirely toward the use of 15 cycles, which undoubtedly represents material advantages over 25 cycles, which has been the more common practice in this country. In Europe, however, in adopting this frequency, the electrification of the main railways has always been in mind. In this country, in practically all of the later large propositions which have been worked up, a frequency of 15 cycles has also been proposed for single-phase work.

In electric locomotive construction there has been a very strong tendency to depart from the older gearless type; that is, those with the armatures mounted directly on the axles. In practically all the newer designs the motors are connected to the axles either by gears or side-rods, or a combination of both. Each arrangement has some advantages, but either the geared, or the gear-and-side-rod arrangement appears to have the preference for slow speed locomotives. In some European three-phase locomotives, however, the side-rod construction is used even for comparatively low speeds.

On large car equipments and locomotives the tendency is to-

ward artificial cooling of the motors and other apparatus. The principal object of this is to reduce the weight of electrical equipment and to increase the continuous capacity compared with the usual one-hour rating. This is particularly important in those equipments which have fairly steady and long continued service.

In motors for general industrial work there are certain pronounced tendencies at the present time. In direct-current motors, the interpole construction is being general adopted both for constant and variable speeds, except for very small sizes. There is a tendency in direct-current industrial motors toward some specialization of lines, that is, where the business is large enough certain lines are built especially for heavy service, such as mill work, etc. Such motors are built to meet some very difficult requirements, which influence the cost and general construction, and are not needed for ordinary service.

In induction motors there is somewhat the same tendency toward specialization of classes as in the case of direct-current machines. There is one special field for the induction motor which has been growing rapidly of late, namely, its application to heavy mill work, such as operating rolls, etc. Induction motors for such service are of special design and usually of very massive construction. The performances, such as the power-factor and the efficiency, suffer slightly, due to the use of large air-gaps, compared with ordinary induction motor practice. Such motors almost invariably have wound secondaries, in order to allow a limited amount of speed variation by the insertion of resistance, as well as to keep down the current at the time of starting. Such motors are also being made of the multi-speed type, that is, with two or more combinations of poles, in order to give several economical running speeds. On account of the relatively low speed of most of these large mill motors, the frequency should be comparatively low, and 25 cycles is coming into very general use for such work.

DEVELOPMENT OF STEAM POWER PLANT MACHINERY

E. H. SNIFFIN

THE year 1910 has witnessed a very substantial progress in the development of power plant machinery. The Westinghouse Machine Company's contribution to this development has been in new designs of steam turbines, in the extension of its

condenser work, and in the application of small turbines to auxiliary purposes, such as operating small generators, boiler feed pumps, etc. It has also brought out the Melville-Macalpine gear for use between turbines and direct-current generators. This device makes possible the use of exhaust steam turbines in connection with slow speed direct-current apparatus. It also enables high pressure condensing turbines to be employed for driving large sized direct-current generators. Embodying, as it does, very small mechanical loss, two percent or less, it permits of the use of the most efficient design of turbine in connection with an efficient direct-current generator. Ordinarily, if the turbine and direct-current generator are direct-connected, it must be at some sacrifice of turbine efficiency, or if the direct current be derived from an alternating-current unit through rotary converters, that also is done with considerable loss in transmission. So the Macalpine gear, where its applicability obtains, adds quite materially to plant efficiency.

Perhaps the most beneficial work done by the Machine Company, in the way of reducing operating cost, has been the very extended application of its exhaust steam turbine. This has particularly occurred in power plants used to operate industrial establishments. Frequent opportunities occur of obtaining increased power by adding to an existing reciprocating engine plant the exhaust turbine, employing to operate it the exhaust steam otherwise going to waste or inefficiently employed, and it is not uncommon to find returns of from 33 to 50 percent upon the exhaust turbine investment. It is, moreover, a very simple piece of apparatus, characteristically free from trouble, and by designing it so that it may operate either with exhaust or live steam, it takes nothing from the flexibility of plant operation, oftentimes greatly improving that feature.

The Machine Company has done enough if it has contributed its share to the great reduction in cost of power plant construction during the last eight or ten years. The prime mover unit itself has been reduced perhaps two-thirds from its cost of ten years ago. The larger units now made possible have brought up the size and reduced the cost of boilers. Condensing apparatus has been made more compact and efficient and lower in cost, and turbine-driven auxiliaries generally employed. The net result has been a general reduction of power plant investment to something like 50 to 60 percent of the valuation that we were formerly accustomed to place upon such properties. Thereby the operating company has enjoyed

a radical reduction in fixed charges, has been placed in better position to afford the introduction of improvements, and has witnessed at the same time a material reduction in operating expense incident to the more simple character of its generating apparatus. And the writer believes that the Machine Company's efforts in the past year, with its high speed turbine development, and with its other new work above noted, have been fully as potential in this direction as any year's accomplishments in its history.

RECENT PROGRESS IN AIR BRAKE APPARATUS FOR ELECTRIC AND STEAM ROAD SERVICE

S. W. DUDLEY

THE development and progress of the transportation facilities of this country have by no means lagged behind the continuous and rapid growth in other directions during recent years. New conditions have created new requirements so important as to demand better road-beds, bigger locomotives, special types of motive power apparatus, heavier cars, higher speeds, and, as a natural consequence, a necessity for improved appliances for controlling train movements.

It may be fairly stated that the last twelve months have witnessed the satisfactory solution of some of the most difficult problems which have thus far arisen in connection with the controlling of electric and steam railroad trains. The general and fundamental characteristics of the improved forms of air brake apparatus required by the intensive demands of modern traffic have been clearly established, reduced to practicable form and introduced to such an extent and for such a period of time as to insure their permanency and capacity to satisfactorily meet the general operative requirements of the future as far as they can be anticipated.

There remain, however, certain special classes of service or extremes of operating conditions requiring greater specialization of apparatus in order to provide for maximum convenience, economy and safety of operation. It is with reference to such instances rather than in the further development of the general functional features of the air brake system, as a whole, that the most notable progress of the past year has been made.

These more specialized developments may be classified as follows:—

1—The electro-pneumatic brake system for controlling the air

brakes on electric trains (such as used in elevated and subway service) by means of electrically actuated valves.

2—The automatic car and air coupler, providing for the connecting and locking of the car and air connections simultaneously and automatically, developed with particular reference to electric train service.

3—The governor synchronizing system for insuring a proper and equal distribution of the labor of supplying compressed air for braking and other purposes between two or more motor-driven air compressors that may be associated in the same train.

4—The control valve brake equipment—an improved pneumatic brake containing a number of novel and advantageous features particularly designed to meet the requirements of heavy, high-speed steam road passenger service.

5—The "empty and load" brake for freight service; designed to provide braking powers for loaded freight cars more nearly proportionate to those realized on empty cars, than can be secured with the standard form of freight car brake.

THE ELECTRO-PNEUMATIC BRAKE

The electro-pneumatic brake, while by no means a new type of brake apparatus, has been developed and perfected during the past year to a point which established it as a wholly practicable and the most nearly perfect brake system yet devised for controlling trains operating under the severest conditions. To the fundamental and most improved type of purely pneumatic brake, the addition of electrically actuated valves affords means whereby the brake may be controlled electrically in applying and releasing for ordinary service operation. The promptness, uniformity and sensitiveness of the brake action made possible by this form of control afford a maximum of simplicity, convenience and economy in train service where frequent and quick stops must be made. The addition of these features to the pneumatic form of equipment, without disturbing the pneumatic features of the brake in any way, adds a safety and protective feature to the combination, which is of the utmost value as insurance against loss of brake power. That is to say, with the electro-pneumatic form of brake equipment the brakes can be applied and released through the medium of the electrically controlled application and release valves without in any way detracting from the responsiveness or efficiency of the pneu-

matic side of the equipment, should the power fail, or should it, for any reason, become necessary to operate the brakes pneumatically instead of electrically. These features of the electro-pneumatic form of brake equipment have been characteristic of previous development in this type of apparatus, but have been combined and extended to a considerable extent in the recently perfected form of this equipment.

In addition, there have been new features added which largely increase the safety and efficiency of this form of equipment. The most important of these is the electric transmission of quick action to the brakes on all cars in the train in emergency applications. This insures simultaneous and instantaneous application of the brakes on every car to their maximum power, resulting in a gain of about one second and one-half in the time of obtaining maximum braking power on all cars of a ten-car train as compared with the best which could be obtained from the most improved form of pneumatic emergency brake. This saving in time is of great value where the service is congested and the speeds relatively high.

The difference between the maximum service braking power and the maximum available for emergency applications has been considerably increased to afford the greatest possible retarding effort when needed, that is consistent with freedom from wheel sliding.

The valves which have to do with producing the quick action application of the brakes are separated from those which are operative in ordinary service applications, with a resulting improvement in freedom from trouble on the road, due to quick action being obtained when not intended. All of the previous types of brake equipment were more or less subject to inconvenience from this source under certain conditions of incorrect manipulation, lack of proper maintenance or adjustment, weather conditions, etc.

The electro-pneumatic brake is at present standard on the cars of the Philadelphia Rapid Transit Company, the Interborough Rapid Transit Company subway, the Hudson & Manhattan tunnel system and the Boston Elevated Railroad.

While the electro-pneumatic brake has been developed with particular reference to the necessities of short-headway, high-speed electric train service as exemplified in the subway and elevated systems just mentioned, its advantages are of equal importance in steam railroad service, particularly where the conditions of operation approximate those of these electric installations.

The advent of train lighting by electricity and the rapid increase of knowledge of and experience with electrically operated devices in steam railroad service are bringing about conditions highly favorable to the introduction of electro-pneumatic apparatus wherever its superior operative and mechanical features are demonstrable. This phase of the situation has been constantly in mind during the development of the recent improved type of electro-pneumatic brake apparatus, with the result that in its final perfected form, the electro-pneumatic brake is capable of extension to any degree required by present or future demands, in either electric or steam road passenger train service, so far as can be at present foreseen.

THE AUTOMATIC CAR AND AIR COUPLER

Various more or less successful forms of automatic connectors for making draw-bar and air hose connections at the same time and automatically have been in service for some time, especially in electric traction service. During the past year, however, a form of this device has been developed which contains certain improved features adaptable particularly to the conditions of subway or elevated service. Under the extremely severe requirements of such service as that of the Interborough Rapid Transit Company, in New York, it becomes imperative that absolute protection against accidental uncoupling of the draw-bars be secured, which can best be done by the substitution of an unfailing mechanical device, which at the same time affords a vastly increased protection to the railroad employes against unnecessary danger to life. The automatic coupling of the car and air connections has further distinctly economical advantages in the direction of time and maintenance by reducing the time required to make up trains at terminals or couple to or uncouple from cars en route, and by reducing the cost of operation by saving the wear and tear on flexible hose connections. Furthermore, when coupled, all slack between cars is eliminated, (multiple-unit motive power trains permitting this desideratum which is impracticable with trains hauled by a locomotive at the head end), thus insuring against shocks in starting and stopping and largely reducing the possibility of damage to equipment and discomfort to passengers.

The improved form of automatic car and air coupler is being applied to all of the cars of the Interborough Rapid Transit Com-

pany's Subway Division, and has already given ample proof of its efficiency under the extremely severe conditions imposed in this service.

THE GOVERNOR SYNCHRONIZING SYSTEM

This system has been perfected during the last year, and is the most satisfactory and efficient apparatus for the purpose yet devised. Heretofore, in the operation of electric trains containing two or more motor cars, more or less difficulty has been experienced in securing an equitable division of the work of supplying the compressed air required for braking and other purposes among the different motor-driven air compressors included in the train. The result has been that some compressors are overworked, while others are not working up to their full capacity. Such an inequality of compressor operation naturally results in increased wear and tear on the overworked compressors as well as an actual decrease in the available air supply under certain conditions, due to the attendant loss in the efficiency of compressor operation. A number of different schemes for overcoming this difficulty have been tried out. Some have proved quite satisfactory for certain classes of service, but, until the perfection of the governor synchronizing system, there seemed to be no generally satisfactory method of accomplishing the desired results with a uniform type of apparatus applicable to all classes of vehicles and conditions of service operation.

Briefly stated, the characteristic features of the governor synchronizing system are as follows:—

The current supply to the motor of each motor-driven air compressor in a train is controlled by a switch, operated by air pressure as in the ordinary form of electro-pneumatic governor previously used, except that the cutting-in and cutting-out of this switch is controlled by the operation of a magnet valve instead of a pneumatic regulating portion connected to main reservoir pressure, as is the case with the ordinary compressor governor. In the governor synchronizing system, this switch is called the compressor switch. In addition to the compressor switch, a pneumatically controller switch called a master governor is used on each motor car similar in all respects to the previously used electro-pneumatic compressor governor, except that instead of controlling the current supplied to the motors of the motor-driven air compressors, it acts simply as a pilot or master switch to control the magnets which

operate the compressor switches. The magnets of the compressor switches are connected in parallel between the trolley (or positive battery terminal) and a wire, called the synchronizing wire, which runs the entire length of the train. The cutting-in of any master governor connects the synchronizing wire to ground (or negative battery terminal) and thereby operates all the compressor switch magnets. All the main reservoirs in the train are connected by means of a main reservoir line pipe running the entire length of the train and connecting to the pneumatic controlling portion of each master governor. With all the compressors cut out, the pressure in this line being equalized, as soon as this pressure is decreased to a point at which any one of the master controlling mechanisms operates, the closing of this master governor switch supplies current to the magnets of each compressor switch in the train, causing them to operate so as to cut in these switches and start all the compressors simultaneously. Whether one or more of the master governors cuts in at the same time is immaterial, since the compressors will continue to operate and raise the pressure in the main reservoirs on each vehicle, and in the main reservoir line throughout the train, until such time as the controlling portion of the last master governor remaining cut in operates to open the circuit to the compressor switch magnets, which causes all the compressor switches to cut out and stop the operation of all the motor-driven compressors simultaneously. It will be seen that in this way all the compressors are forced to operate the same length of time and since the main reservoir pressure is equalized on all vehicles, the stronger compressors help the weaker ones to the extent of insuring the necessary amount of compressed air being supplied at the expense of a minimum amount of energy, time, and wear and tear on the apparatus.

THE CONTROL VALVE EQUIPMENT

This type of equipment, marking the latest perfected development in the art of braking heavy passenger trains, is a new form of apparatus, fundamentally designed to provide an adequate brake for the heaviest passenger cars now operated or which may be built. During recent years the weights of sleeping and dining cars especially have begun to exceed the capacity of the largest single brake cylinder arrangement, and, as a result of special study of this problem, the control valve equipment was evolved to ob-

viate the necessity for applying two single cylinder duplicate sets of apparatus per car, and to improve certain features inherent in the standard brake design which tend to reduce brake efficiency to a considerable degree when applied to the heaviest types of rolling stock.

Not only were the factors of weight, work to be done per unit of brake shoe area, lower efficiency of foundation brake gear, etc., aggravated to a marked degree, but limiting conditions were encountered in other directions. The capacity of the largest single cylinder (18 inches in diameter) was exceeded, even with the highest brake cylinder pressure that could be permitted. It was generally recognized that a larger size brake cylinder would be impracticable from a manufacturing, operating and maintenance standpoint. A higher pressure than the standard 110 pounds, or a greater increase in the leverage ratio of the foundation brake rigging, above the recommended 9 to 1 maximum value, was impossible with the type of equipment in general service. These and other mechanical limitations barred further progress in the directions previously followed, and a general recognition of the serious nature of the problem confronting the railroads and brake manufacturers resulted in a joint conference and discussion at which representatives of the Master Car Builders' Association and railroads from all parts of the country were present, at Union Station, Pittsburg, Pa., in the late summer of 1909. The tentative recommendations of this meeting were reduced to practice and its conclusions confirmed in a series of high speed passenger brake tests, inaugurated and successfully carried out by the Lake Shore & Michigan Southern Railroad on its main line near Toledo, Ohio, during the fall and early winter of 1909. The fact that these tests were made with the heaviest classes of modern rolling stock, under road conditions representative of the best of modern railroad practice, and the scientific and comprehensive manner in which the tests were conducted and the results analyzed and at once put into effect, give these tests a position of importance second only to the classic Westinghouse-Galton Brake Trials in England during 1878 and 1879.

From a study of the results of these tests, it became evident that, in the first place, two brake cylinders per car were required to provide the necessary power for controlling the heavy types of cars which had to be reckoned with, and, in the second place, suitable valve mechanism was required for properly controlling the operation of these two brake cylinders and securing certain desirable

operative functions heretofore impossible with previous forms of passenger car equipment, as well as permit of ready extension as still more severe demands might arise in the future. These considerations led to the development (during the progress of the tests referred to) of what is known as the "PC" brake equipment, which uses in place of the ordinary triple valve, what is known as a control valve, providing the following features of operation:—1—Automatic in action. 2—Efficiency not materially affected by unequal piston travel or brake cylinder leakage. 3—Prompt serial service action. 4—Graduated release. 5—Quick recharge and consequent ready response of brakes to any brake pipe reduction made at any time. 6—Predetermined and fixed flexibility for service operation. 7—Full emergency pressure obtainable at any time after a full service application. 8—Full emergency pressure applied automatically after any predetermined brake pipe reduction has been made after equalization. 9—Emergency braking power approximately 100 percent greater than the maximum obtainable in service applications. 10—Maximum brake cylinder pressure obtained in the least possible time. 11—Maximum brake cylinder pressure maintained throughout the stop. 12—Brake rigging designed for maximum efficiency. 13—Adaptable to all classes and conditions of service.

All the novel functions mentioned are incorporated in the new device in such a way that the requirements of interchangeability with existing apparatus have been fully satisfied.

THE "EMPTY AND LOAD" BRAKE EQUIPMENT

This type of equipment, while designed with particular reference to the handling of loaded freight cars on grades, has also the same fundamental advantages for baggage and express cars, or for any railroad vehicle which may be classed as a load-carrying car. It will readily be seen that the necessity for operating such cars empty as well as when loaded, requires that the brake shall not be too powerful for the empty weight of the car. Otherwise, wheel-sliding and damaging draw-bar stresses will result.

Various schemes have been proposed and experimented with to a greater or less degree whereby a variable braking power can be obtained, commensurate with the weight carried on the wheels, which will automatically adjust itself to the condition of the car whether it is empty or loaded. While the great desirability of such a form of brake apparatus has long been recognized by all familiar

with the handling of this class of service, there have been mechanical or operative objections to all of the schemes thus far proposed, or certain desirable features have been lacking.

In the form of "empty and load" brake apparatus, which has been perfected during the last few months, advantage has been taken of a broad knowledge of the fundamental principles affecting the operation of braking apparatus from its earliest to its latest forms and of accumulated experience with a number of different types of "empty and load" equipments under a great variety of conditions, with a result that the equipment has been reduced to the minimum number of parts and complication of apparatus consistent with the fundamental features of operation desired.

Two brake cylinders are used, one for the empty car and both together when the car is loaded to say two-thirds or more of its rated capacity. Practically the same valve mechanism is used to control the operation of these two cylinders, except that an additional change-over valve mechanism is added for cutting the "load" brake in or out, either manually, or, under certain circumstances, automatically. The only addition to the foundation brake gear is that required to connect the "load" cylinder with the standard lever arrangement which is still used in connection with the "empty" side of the equipment. On the empty car the operation of the equipment is similar to that of the present type of freight apparatus employing what is known as the type "K" triple valve. When the car is loaded to two-thirds or more of its rated capacity, the "load" side of the equipment is cut in by hand, and the operation of the brake is thereafter that of the "load brake" until manually changed to "empty" or until the air pressure is entirely exhausted from the system.

Moreover, the combining of an automatic change-over from "load" to "empty" on total depletion of the pressure in the air brake system, with a manual change only from "empty" to "load," insures that the brake will always be set for "empty" on the empty car and remain so unless intentionally changed to "load" when the car is loaded. Means are provided so that the device can be locked in either "empty" or "load" position, where it will remain until unlocked and manually changed.

At present this form of brake equipment is being applied particularly to mountain grade service where the capacity of the road is limited by the amount of tonnage which can be safely handled per train down the grade. For such a condition the "empty and

load" form of brake makes it possible to increase the traffic capacity of the road to a considerable extent at a relatively small increase in cost.

It will be recognized, however, that this form of equipment possesses important operative advantages in the direction of greater uniformity of braking effort with empty and loaded cars mixed in the same train, thus largely eliminating shocks and consequent delays and damages to equipment and lading, which now assume enormous proportions. These and other characteristics make it the logical and ideal type of apparatus for load-carrying cars in any kind of service.

PROGRESS IN POWER TRANSMISSION

P. M LINCOLN

IT IS well that one is asked occasionally to count the mile-posts, as it were, particularly for the art of power transmission. The progress of the electric transmission of power has been so natural and so logical that the engineers who are in constant contact with that progress hardly realize that there has been progress until they stop to compare present conditions with those of a year ago, or five years ago, or ten years ago. The outsider, the man who only occasionally comes into contact with the art, better realizes the progress than the engineer whose work helps make that progress possible.

During the year of 1910, probably the most notable event so far as transmission matters are concerned is the inauguration of service over the lines of the Hydro-Electric Power Commission of Ontario. This transmission system is operated at 110 000 volts and covers a large part of Southern Ontario adjacent to Niagara Falls. The use of 110 000 volts for transmission purposes is now well established, there being at least a half-dozen plants in which this voltage is used. Already designs are being undertaken for the next advance, and 140 000 volt apparatus is already being demanded by certain projects which apparently do not show a possibility of success without this high voltage, and the design and construction of apparatus for this voltage is already under way. Further, the designing engineer must now begin to recognize that he must hold himself in readiness to meet even the next step, which will bring the voltage of transmission to perhaps 165 000. In this connection it is significant that a test on the lines of the Hydro-

Electric Commission mentioned above was successfully carried out at 165 000 volts. So far as types of construction are concerned, the underhung insulator is being used on all of the 100 000 volt lines and, so far as line insulation is concerned, it seems to have been a very satisfactory solution to the problem.

Another method of construction that seems fairly well established is the use of steel transmission towers and long spans. In practically all recent high-voltage transmissions this form of construction is being used. It is particularly adaptable to rough country, where the spans can be designed so as to leap from hill to hill, and thus avoid the expense of carrying the lines into deep cuts or inaccessible gulches.

The transformer designer is probably the one who has the least to fear from the continual increase in transmission voltages. Cases of transformer breakdown are exceedingly rare in modern transformers, thus showing that the modern methods of insulation, *particularly the strengthening of insulation between turns,* has been a complete answer to the transformer problem. Another great help to the transformer designer is the existence of the condenser bushing. This bushing gives the designer a reliable solution to the problem of bringing his leads through the metallic transformer case. This bushing also enables the oil switch designer to take care of practically any transmission voltage within present prospect.

In conclusion, attention is again called to the fact that, although present conditions in transmission are striking when compared with conditions of ten years ago, the arrival at such conditions has been so natural and logical a process of evolution that it is more or less difficult to pick out any one item from the sum total and say that it is responsible for any large proportion of this remarkable advance.

IMPROVEMENTS IN RAILWAY SIGNALING

J. S. HOBSON
Assistant General Manager,
The Union Switch and Signal Company

IT IS somewhat difficult to point out particular improvements in railway signaling material and methods made during the last twelve months which are sufficiently marked to be interesting to anyone not familiar with the details of the subject. In general, the progress made in our branch of engineering has been more along the lines of developing designs already in general use, than

in making radical changes in design or in placing entirely new apparatus on the market.

The interlocking and signaling for the new terminal of the Pennsylvania Railroad in New York City is a striking example of this, since, while that installation is the very latest development in railway signaling, it differs little in general principles from similar plants installed during the past five years. The most noteworthy features of this installation comprise means for obtaining the positive control of interlocked signals by the actual position of the switches or switch they govern; the automatic control of such signals by track conditions; the automatic locking of all switches in every route by the entrance of trains thereon, and their automatic release immediately the rear end of a train has passed clear of the fouling point of the track including each switch. The special features further comprise means for giving visual indications to the tower operator of every act of a train in actually locking and releasing levers controlling switch and signal operation, and means for permitting the joint use of all tracks for traffic in either direction between adjacent towers, by the co-action of towermen and track conditions.

The foregoing are, however, developments of methods previously in use in other plants, and while, in a sense, improvements, are not radical. There is, however, one somewhat original improvement in the Pennsylvania Terminal installation, used for the first time to any extent; namely, the control of electro-pneumatic valves through magnets actuated by alternating current. The use of alternating current for the operation of signal apparatus has been steadily growing for the past seven years, and the twelvemonth just passed represents a more rapid growth of its use than any previous year. Alternating current was first used to any extent in signal apparatus for the operation of track circuits on electric railways, employing either alternating or direct current for propulsion purposes, but now its use has gradually been extended to the operation of signals, indicators, locks, etc.

A new field has very lately been opened for signal apparatus on interurban electric railways, the managers of which are taking a very keen interest in this subject, several contracts of this kind having just been closed by this company. Since their conditions differ somewhat from the electrified sections of steam railroads, certain modifications have been made in alternating-current signal apparatus, resulting in improvements tending to increase its ef-

ficiency. For example, by modifications in the design of alternating-current relays, transformers, etc., the length of track circuits which can be operated without relaying has been materially increased, and the cost of installing alternating-current automatic block systems reduced accordingly.

The only other striking improvement in signal apparatus has been the development of the electro-mechanical interlocking system, in which the switches and their locks are operated manually and controlled electrically, the signals being electrically operated. This system possesses the combined safety features of manual and power operated interlockings at a cost about midway between the two. Its use is confined to plants where the farthest switch is located within about 800 feet of the operating levers, and so far it has not been applied to interlockings of any considerable magnitude, or where the rapid operation of switches and signals is necessary, such as in terminal yards. However, very many interlockings can be satisfactorily operated by it, and its use is rapidly increasing.

Numerous minor developments in products have been made during the past year, as, for example, the improving of insulation in electrical material, the standardization of details to fit them for more universal application, and the modification of designs to cheapen the cost of production and expedite delivery of orders, among which may be mentioned the substitution of drop forgings for parts previously made of malleable iron, which from the nature of its manufacture cannot be furnished on short notice.

As an example of the improvement in the design of electrical apparatus, porcelain and insulating moulded material has been substituted, in many instances, for parts previously made of metal and insulated from their electrical connections by bushings and washers.

THE NATIONAL ELECTRIC LIGHT ASSOCIATION

W. W. FREEMAN,
President

THE year 1910 has been one of activity and marked progress for the National Electric Light Association. The annual convention, held in St. Louis in May, was the largest in the history of the association, having over 2 700 registered delegates, and the twenty-fifth anniversary of the organization was fittingly celebrated at that time.

The routine work accomplished at the association headquarters in New York by the secretary, Mr. T. C. Martin, and his staff, has grown rapidly, and demonstrates in constantly increasing measure the value of the organization to the entire industry.

The standing committees have been increased in number and in members and now include more than 150 individuals, who are engaged in research or formulative work for the benefit of the entire membership. Thus the important work is continued throughout the year, and focused into the annual convention.

The membership of the association has increased more than 1 500 during the year and now exceeds 6 000, of which over 900 consist of central station companies, known as Class A members.

The organization of company sections has been a marked feature of the past two years, and thriving sections now exist in Altoona, Pa.; Brooklyn, N. Y.; Boston, Mass.; Birmingham, Ala.; Baltimore, Md.; Buffalo, N. Y.; Chicago, Ill.; Connellsville, Pa.; Chattanooga, Tenn.; Denver, Colo.; Dayton, Ohio; Des Moines, Ia.; Detroit, Mich.; Evanston, Ill.; Mt. Vernon, N. Y.; Newark, N. J.; New York, N. Y.; Philadelphia, Pa.; Rochester, N. Y.; Reading, Pa.; Salt Lake City, Utah; Savannah, Ga.; San Antonio, Texas; St. Louis, Mo.; Toronto, Ontario; Vancouver, B. C., and Washington, D. C. This plan of organization is proving beneficial both to the association and to the companies, and a further increase in membership of several thousand may be depended upon in the near future.

Geographic sections are flourishing in different parts of the country, several having been formed during the year. Several national special sections are also in process of formation. A commercial section and a power transmission section have been organized and will begin active operations promptly. Each of these subdivisions of organization is provided for in the constitution of the association, and a thoroughly comprehensive and complete organization of the industry is being carried out upon a broad and permanent basis.

All issues embraced in the general idea of public policy have received the serious and practical consideration of the Public Policy Committee, which is representative of the best talent and most extensive experience of the industry. This committee is making history for the association and is rendering a public service, the value of which has been appreciated most positively in several instances during the past year.

The electric lighting companies of the country have in general had a prosperous year. Problems, both old and new, have not been lacking, but they invariably yield to solution through the exercise of persistent industry and ingenuity. No industry has a brighter future and none deserves one.

GROWTH OF THE INCANDESCENT LIGHTING INDUSTRY

G. P. SCHOLL

DURING the year 1910 the incandescent lighting industry has made rapid progress not only in the development of the tungsten lamp but also in the improvement in the quality of the carbon lamp. In former years the manufacture of incandescent lamps was largely developed from what might be called the practical manufacturing side, and the methods employed were largely based upon rules of thumb. This state of affairs has been changed entirely and the advent of the tungsten lamp, with its greater demands on technical and engineering skill, has contributed not a little to the change. All of the principal lamp manufacturing companies are maintaining at the present time a large staff of chemical and engineering experts, employed purely in development and research work, and their labors are gradually establishing the manufacture of incandescent lamps on a firm scientific basis. The improvement of the average quality of the product turned out by the factories of course goes hand in hand with this.

The greatest progress during the year has naturally been made in the domain of the tungsten lamp. An extended study of the chemical and physical characteristics of the metal tungsten, coupled with an increased experience in the methods of manipulating it, has resulted in the development of different processes of manufacture, which have improved the quality of the lamp. It has, moreover, led to the manufacture on a large scale of continuous tungsten filaments, which makes it possible to do away with the number of individual filaments which had to be used formerly in the tungsten lamp and to make a new type of lamp in which the filament consists only of one continuous piece. Great improvements have also been made in the methods of mechanically supporting the continuous filament in the lamp, in the proper dimensioning and choice of material for these supports, and in a most efficient and effective method of connecting the continuous filament to the leading-in wires of

the lamp. The Westinghouse Lamp Company has the distinction of being the pioneer in this field, as it was the first to bring out a lamp of this type. It needs no argumentation to show that a lamp which has only one continuous filament and in which there are no rigid joints connecting the filament ends to the leading-in wires and to the anchor wires, is considerably better adapted for all practical uses than a lamp of the old type with its multiplicity of mechanically weak joints.

A most notable advance in the general application of the tungsten lamp has been its encroachment upon the field formerly occupied by the arc lamp and which has led to the construction of tungsten lamps of very high wattages and corresponding high candle-power, such as the 250, 400 and 500 watt types, and even to the construction of 1 000 watt lamps. It appears that in this country we are pursuing a course somewhat similar to that followed in Europe, where at the present time large numbers of these high candle-power tungsten lamps are marketed in the field formerly occupied by the arc lamp. There is no doubt that this progress will continue, and the tungsten lamp will still further encroach upon the field which was formerly supposed to be entirely reserved for the arc lamp.

It is a further notable fact that the increased use of the high efficiency metallic filament lamp has developed a much more intelligent application of lamps in general, so that a higher percentage of the light produced by the lamp is now utilized than ever before. This improvement has been brought about by the more extended scientific study of the physical characteristics of incandescent lamps and their accessories, especially the reflectors. The broad-minded policy of the largest of the manufacturers of these accessories in establishing scientific research departments and putting the results obtained at the disposal of the interested parties has contributed largely towards this result. A not inconsiderable share of the progress made in the instruction of the general public in the intelligent utilization of incandescent lamps is due to the labors of illuminating engineers.

The demand from the general public, architects, central station managers and other users of illuminants for correct and scientific information on the proper use of incandescent lamps is rapidly bringing about a new era in illumination, which is developing new fields and new users for incandescent lamps, heretofore supplied from entirely different sources of light, many of which have

been more or less dangerous. A significant fact in this connection is the increased consumption of lamps by one of the large railroad systems, which has doubled the preceding year's consumption each year for the past four years, and from present indications will approximately double its already large consumption in the ensuing year.

In line with the general progress made in the application of correct scientific principles to the art of illumination, the suggestion of holding a course of instruction on illumination met with hearty approval and resulted in an attendance of over 200 at a course given at Johns Hopkins University the latter part of October.

As a matter of general interest it might be mentioned in conclusion that the total number of lamps manufactured in the United States and sold to domestic consumption for the year ending September 30th was between seventy and eighty millions. During the year the use of the tungsten lamp increased approximately 100 percent, while the use of the carbon lamp remained practically the same.

THE GREATEST RAILROAD WORK IN HISTORY

F. H. SHEPARD

NOVEMBER 27, 1910, marks the culmination of the greatest single railroad achievement in history, the inauguration of the service of the extension of the Pennsylvania Railroad into New York City. The grandeur and beauty of the New York station is a fitting monument to the accomplishment of this great engineering triumph, and the advantage gained to New York, destined before long to be the metropolis of the world, will be a benefaction to this and to succeeding generations.

The Pennsylvania Railroad is one of great achievements. Its practice is always of the best, and it has shown the way for most of the improvements and present day standards in American railroading. It should be the cause of supreme satisfaction to all engineers to know that this gateway to New York City was predicated entirely upon the use of electricity. The topography of Manhattan Island interposed a limitation to its transportation facilities both East and West, which was scarcely intended for mere man to overcome, for a main line railroad entrance into the heart of New York City. With eighteen miles of track in tunnels and sixteen miles in the station area in the heart of New York, electric motive power

was the only feasible solution. The acquisition of the Long Island Railroad and its need for direct entrance to Manhattan, secured nearly ten years ago a comprehensive plan for common improvement.

Since 1902, coincident with the building of tunnels and station, the electrical problem has been under constant development. The requirement for earlier electric operation of Long Island service on the Atlantic Avenue improvement in Brooklyn led to the construction of the Pennsylvania power house in Long Island City and its operation in 1905 to furnish power for the 100 miles of Long Island track then electrified. This site is laid out for an ultimate generating capacity of 100 000 kilowatts, and was practically the first railway station designed to use steam turbo-generators. The Long Island traffic is essentially suburban and is cared for by motor car trains, some 500 or more being operated daily.

For the handling of the through traffic from the West and South electric locomotives supplant steam power at Manhattan Transfer, near Newark, New Jersey. For this service unquestionably the most remarkable motive-power unit on wheels is used. The study, investigation and experimentation which preceded the construction of these locomotives is without a parallel. It was not alone to transform electric power into a guaranteed tractive effort of 60 000 pounds per locomotive, shown on test to equal 80 000 pounds, to handle heavy trains at 65 miles an hour and more, but to incorporate these characteristics in a machine which would equal, if not excel, the best operating features of a steam locomotive. A common current input is 7 000 amperes for each locomotive at 650 volts, and on the test of a single motor 4 500 amperes has been reached. The locomotives are amply equipped with switches and other devices to handle these heavy current inputs, but in comparison with power house service they operate many times more often. The efficiency with which this is done is conspicuous, any one of the switches being able to rupture the entire current, and, although with a crash somewhat resembling the report of a cannon, with hardly a distinguishable flash even on the arcing tips.

The power supply for such machines, two of which may be coupled to a single train, and with six or eight trains on a single section, is enormous. The current supply is directly from a rail of 150 pounds section supplemented by a cross-connection to the other tracks and copper feeders. During a rush of current on short-circuit some 50 000 amperes has been recorded, and even

this can be considerably exceeded. The capacity for handling these currents through the switching apparatus and even back to the power house is extraordinary.

The maze of plans for this great work, second in magnitude only to the Panama Canal, is almost beyond comprehension. Most notable, too, is the success attending the initial operation of this service. Up to this time, three weeks from its commencement, there has not been a single delay due to any feature of electrical operation from power house to rolling stock. This is emphatic endorsement of the design, engineering and execution of all those interests and individuals who have participated.

In this development the engineering forces of the Pennsylvania Railroad and those of the Westinghouse Company have been for years in continuous coöperation.

INDUSTRIAL MOTOR APPLICATIONS

D. E. CARPENTER

IN THE field of industrial motor applications, the past year has seen closer study of conditions and a more intelligent effort to meet them. The motor manufacturers have shown increased activity in collecting information from motor installations already in operation. Tests have been made by the aid of the graphic meter and other instruments, and the data thus obtained has proven of great value. Not only has the operation of existing installations been improved, but new applications have been made in a more intelligent manner than ever before. The day has passed when the interest of the successful motor builder ceased with the sale of his product. He now aims to see that his motors are not only properly built, but also selected and applied in each industry in a way to insure the best possible service.

While no radical departures from previously well established practice have been attempted, many important improvements have been made. With proper information available, the motor characteristics required for a given application can be quite definitely determined, and engineers now have little difficulty in designing motors with characteristics ranging between wide limits.

Improved methods of motor control have also contributed largely to the increasing success of motor drive. Safeguards have been added to control devices, rendering them more suitable for operation by unskilled operatives. Some progress has also been made

in automatic control features, especially in connection with the operation of apparatus performing a definitely known cycle of operations.

The extent to which electric motors have supplemented other forms of motive power in heavy service finds an excellent illustration in the steel mills at Gary, Indiana. Here the completeness of the motor equipment has made possible the introduction of fuel economies greater than ever before attempted. The past year has seen the new equipment brought into successful operation and has demonstrated its ability to obtain minimum cost of production.

Another application of large electric units is the operation of mine hoists. The year just closed has seen the methods of control of large motors operating mine hoists brought nearer to perfection, with correspondingly pleasing results. The economy with which electric power can be transmitted to a distant mine from a power house, located where it can be operated under the most advantageous conditions, makes the electric operation of mine hoists particularly desirable.

During 1910 some entirely new motors have been put on the market, especially adapted to specific industries. Many improvements in existing designs have also been made in order the better to adapt motors to the work they are to perform. Probably the steel and iron mills have called out more new designs recently than any other one industry. Direct-current motors for mill and crane service had previously been developed, but the past year has seen the introduction of several new alternating current motors for such service. These motors are of both the squirrel-cage and the slip-ring types, and are characterized by great solidity, rugged strength and evident durability, coupled with simplicity of construction and ease of repair. Both types of motors have been designed with the broadest possible field of application in view; both are giving good service, not only in and around steel and iron mills, but also in cement mills and in other places where severe service under adverse conditions must be expected.

Squirrel-cage induction motors have been applied more extensively and more successfully than ever before to service requiring high starting torque, such as the operation of elevators. An elevator motor of this character recently placed on the market is so designed that it starts on full voltage with maximum torque and without excessive current. Necessarily its slip is high, giving characteristics perfectly suited to elevator operation. The motor is con-

trolled by a simple reversing switch. It starts at slow speed which increases gradually to full speed after the elevator is under headway.

An application of electric motors which has increased very rapidly is to the driving of pumps for irrigation purposes. The wonderful results obtained where the supply of water to growing crops has been artificially regulated have awakened the farmers to their opportunities. Electric energy is readily carried anywhere within many miles of the generator, and a motor-driven pump can be easily installed beside any convenient lake or stream or over a well. An abundant supply of water can thereby be supplied to a considerable tract, producing an amazing increase in the value of crops harvested.

The textile industries have not by any means been neglected. The requirements in this service are somewhat peculiar and are such as were formerly thought to be beyond the possibilities for electric motors. The special motors placed on the market two or three years ago have been brought into more extensive service than ever before and have proved themselves capable of operating successfully in the damp atmosphere of the dye houses as well as in the dust and lint-laden atmosphere of the picker room and the carding, spinning and weaving rooms. These motors can be wound for rapid starting with very high torque, as required by looms, or they can be wound for slower starting with lower torque, as required by some other textile machines.

Great activity has been shown in the production of electric vehicles for both pleasure and business. Improvements in storage battery design have increased the radius within which such vehicles can be operated successfully, and large numbers of them are being utilized. Modern vehicle motors and controllers are showing remarkable reliability and endurance on all sizes and varieties of vehicles and under all conditions.

Small motor applications have increased in number to a marked degree. Motor-driven washing machines, vacuum cleaners, sewing machines, buffing and polishing machines, shoe polishers, hat cleaners, coin counters, envelope sealers and stampers, sign flashers, small drills and grinders, etc., are now in use by thousands and their number is rapidly increasing. Almost every field where light work of a laborious character is to be performed is being preëmpted by some small motor-driven device.

A general utility motor, which can be readily adapted to any one of several different household services, has also been market-

ed. This motor can be made to run the sewing machine, polish the silverware, grind the knives, ventilate the rooms and operate a small lathe or other tools.

While, as before stated, the progress during 1910 in industrial motors and their application has been along lines previously fairly well known, yet there has been progress of a marked degree. At the same time need of still further improvement has been manifested, and new methods and designs will doubtless be forthcoming.

ELECTRICITY IN THE STEEL INDUSTRY

BRENT WILEY

THE economies afforded by the broad application of electric power in steel plants have resulted in a great activity in this field during the last few years. Today there are numerous steel mills equipped universally with electric power with a total capacity of about 150 000 horse-power in large motor units. The various types of mills provided with electric drive during the past year are:—Sheet mills; merchant mills of various sizes—9, 10, 12, 14 and 18-inch; jobbing plate mills; skelp mills, and plate mills.

Many of the new power-house installations, include gas engines, which utilize the gas from the blast furnaces. The low pressure steam turbine units, using the exhaust steam from engines, have also been the means of giving practically 75 percent additional power without increase in the fuel costs. Several installations of this type have been made during the last two years, and among these are:—The American Steel & Wire Company, one 300 kw unit and one 750 kw unit; the American Iron & Steel Manufacturing Company, one 1 000 kw unit; the American Rolling Mill Company, two 1 500 kw units; the National Tube Company, one 1 000 kw unit and three 1 500 kw units; the Pittsburg Steel Company, one 1 000 kw unit; the Pressed Steel Car Company, one 500 kw unit and one 1 000 kw unit; the Republic Iron & Steel Company, two 600 kw units; the Standard Steel Works, two 500 kw units; the Wisconsin Steel Company, one 750 kw unit.

For the large steel mill of today, the standard characteristics of the electric power are three phase, twenty-five cycle and either sixty-six hundred or twenty-two hundred volts, with but a few exceptions. The high voltage offers many advantages in the distribu-

tion of power for large plants, and the frequency of 25 cycles gives a relatively low speed range for the design of large motors. This is often a point of advantage in connecting the motor to the mill, and the tendency is to eliminate gears, ropes and belts and direct connect the motor to the mill.

A number of the older mills equipped with direct current only have installed low pressure direct-current turbine units within a comparatively recent period and these units have been of three types:—

1—Steam turbines direct connected to 250 volt, direct-current turbo-generators (the maximum size being 750 kw at 1 500 r.p.m.).

2—Steam turbines direct connected to six-phase, 60-cycle, 178 volt, alternating-current generators operating at 3 600 r.p.m., maximum speed, with leads direct connected to a 250 volt rotary converter, the entire unit being treated as a direct-current machine.

3—Steam turbines (3 600 r.p.m., maximum speed,) connected to 250 volt direct-current generators by gear reduction of the Melville-Macalpine type.

During the last year all improvements of any importance in the steel mills have included the installation of large motors for the rolls. The large roll motor of today is, with but few exceptions, of the alternating-current, wound-rotor type. Where adjustable speed is required, the motor is so constructed that various combinations of poles can be obtained. Special attention is given the mechanical features and provisions are made to relieve the motor of all possible shocks and strains due to unusual conditions, such as the breaking of the mill spindle.

The direct-current mill motor, while not a product of 1910, has been an improvement of a comparatively recent period, and for auxiliary service on machines having heavy intermittent duty, such as mill tables, screw-downs, transfers, charging machines, and ladle cranes, has been wonderfully effective in reducing operating costs. The repairs to the motors are very small and their efficiency of operation is high, a shut-down due to motor trouble being of rare occurrence. The motors are of very rugged construction; the frames are of the horizontal split, box type, with well braced feet supports of steel, and are made with and without counter-shaft bearing brackets. The armature shafts are large and are made of forged axle steel; the armature coils are well supported at the ends and are held in place firmly; the insulation of both the arma-

ture and field coils is of fireproof construction and at even high temperatures there is no undue deterioration; the motor is readily accessible for inspection and repairs, and the speeds are moderate.

While it is a fact that the characteristics of the direct-current motor make it admirably suited for the general class of mill work, there has been a decided increase in the application of alternating-current motors on auxiliary machines during the last twelve to eighteen months. The advantages offered by he latter type of motor are lower first cost and higher operating efficiency, and, for large installations especially, these advantages are sure to bring the alternating-current motor into more universal use. The simplicity of construction of the squirrel-cage type of motor for continuous service, similar to shear or saw duty, is also a particularly favorable feature.

The present day alternating-current squirrel cage motor for mill work is constructed for heavy duty, with strong, massive frame and large shaft, and it is designed, in all its mechanical and electrical features, to withstand severe service in a durable manner. Decided improvements in all types of alternating-current motors will be made to meet the demands of the steel mill requirements in a manner very similar to the advance which has been made in direct-current motors, and even now we have the following applications of alternating-current motors in the mills:—Cranes, charging machines, mill tables, transfers, shears, saws, straightening machines, conveyors, and various classes of finishing machines.

The magnetic switch controller, a development of a comparatively recent period, has been one of the leading factors in the improvement of motor operation for the intermittent duty in particular. The controller proper is operated by means of a master switch, which can be located at any convenient point, and which requires but little energy on the part of the operator. The operator's pulpit can, therefore, be located to the best advantage, and the number of operators is greatly reduced as compared with the number required by the old mill layouts. While the older forms of rheostatic controllers are still used for intermittent service motors up to and including the 50 horse-power size, the magnetic switch controller is used almost universally for the larger sizes. They are much more durable, they prevent abuse of the motor by giving automatic acceleration, and various features such as dynamic braking, automatic starting and stopping, and overload and no voltage protection can be incorporated easily.

The most recent new application of electric power in the steel industries is that of the electric furnace. During the year 1910 the output of electric steel was approximately 100 000 tons, and the furnaces in operation were:—The Halcomb Steel Company, one four-ton Heroult electric furnace; the Firth Sterling Steel Company, one three-ton electric furnace arc type and one 1½-ton electric furnace, resistance type; the Illinois Steel Company, South Works, one 15-ton Heroult electric furnace; the Homestead Steel Works, Carnegie Steel Company, one 15-ton Heroult electric furnace; the American Steel & Wire Company, Worcester Works, one 15-ton Heroult electric furnace.

This is a new art in this country and the possibilities offered by the electric furnace are known in a small measure only. The principal field of the electric furnace is that of refining, and at the present time the largest furnaces are used as part of a duplex system. The steel is first partially refined in the bessemer converter or open-hearth furnace then finished in the electric furnace. The grade of steel is superior to that produced by the older process (the crucible process being excepted), and the cost is but slightly increased.

SINGLE-PHASE EXTENSION ON THE NEW HAVEN SYSTEM

W. S. MURRAY
Electrical Engineer

BRIEFLY reviewing the progress of the year 1910 in matters pertaining to electric railway engineering and construction, the most important development, in my opinion, is embraced in the undertaking of the New York, New Haven & Hartford Railroad for the extension of electric service to completely cover passenger, freight, and switching service under trunk line conditions on the Harlem River Branch. This extension, which connects with the present main line electrification at New Rochelle Junction, will enable all train and switching movements on the New Haven system west of Stamford to be made electrically. By this electrification some 200 miles of track, measured on a single-track basis, will be added to the 100 miles already electrified.

It may be of interest to note that the New Haven is the first steam railroad in this country which, having changed to electrical operation, has made an extended addition to the system. The

fact that this extension is made with 11 000 volt single-phase overhead construction and the fact that the Hoosac Tunnel is now being elecrically equipped by the same system give a practical verdict upon the past few years' operation of this system. It may be added that the Hoosac Tunnel electrification is isolated and a long distance from the New York division electrification. There was, therefore, no immediate reason why either the direct-current or the three-phase system might not have been used for the tunnel, had there been any misgiving as to the suitability of the single-phase system.

Far more important, in my opinion, than the above concrete fact is the evidence that a clearer conception of the proper classification of systems of electrification is being brought about by the results obtained in actual practice. With respect to their applicability to various kinds of service, I am happy to find a general concurrence of opinion among men of my profession in the conclusion that the high voltage single-phase system is the proper electric power to apply to trunk line trains, inclusive of terminals and suburban territory. As completely as the direct-current system is superior to the single-phase system in city streets and suburban connections of not too great distance, so in the larger field of heavy electric traction, as, for instance, trunk line electrification, the single-phase system has demonstrated its superiority over the direct-current. This statement applies even in the case of electrification of trunk lines of the character that obtain in the Middle Atlantic coast territory, where only electric passenger operation is contemplated. Add to this the movement of freight by electricity, and the comparison of net costs between the direct-current and single-phase systems is astonishingly in favor of single-phase.

An investigation into the percentage of "yard mileage" to main line mileage in the above-mentioned territory would yield a surprise, I am sure, to many; this ratio being remarkably large. Freight cars lying in switching and classification yards are not earning money, and it is only when the cars are made up into a train, with their merchandise in movement toward its destination, that they become revenue producers. Thus, it is patent that we should not have to spend a great deal of money on this unproductive yard mileage. Only recently I heard an advocate of the third-rail system say, "Well, we have brought the cost down to $6 000 a mile". This did not include feeders, sub-stations or anything else—just third rail. A yard recently electrified for single-phase service cost

$1 800 a mile—no feeders required. Thus, with the single-phase system we are enabled to electrify yards at a cost which is 25 per-cent of that required in the case of the direct-current third-rail system; and the power for the switching engine is twenty-two feet out of the way, while, in the case of the direct-current, the third rail is continually 18 inches in the way, especially when some one is in a hurry to cross the yard.

The study has been exhaustive; the conclusion not hypothetical but practically proved. There may eventually be found a better system than the single-phase for heavy trunk line electrification, inclusive of suburban and terminal service, but it has been clearly demonstrated that it is not the direct-current system. The single-phase system lies between it and the as yet undiscovered system.

CHANGES IN THE ELECTRIC RAILWAY FIELD

N. W. STORER

THE year 1910 has not seen many startling changes in the electric railway field. It has, however, been marked by a steady improvement in apparatus, and by an awakening on the part of operators to the enormous savings that can be made in power consumption by proper attention to the design of cars and equipments to secure minimum weight and correct methods of operation so as to get the minimum watt-hours per ton-mile. The introduction of the coasting time clock by the Interborough Company in New York City has done much to prove what has always been realized; that is, the savings in power consumption by rapid acceleration and braking, and long coasting. The experiments with ball and roller bearings are in the same line. The development of the light storage battery car calls attention to the great reductions in weight that are possible by special designs, and to the enormous reduction in power consumption by low speed gearing. From the above it is plain that the economies resulting from such features are going to be rigidly inquired into hereafter by all thinking operators.

The interpole motor has still further extended its hold on the railway field and is giving universal satisfaction. All sizes of these motors, from the giants on the Pennsylvania Tunnel and Terminal locomotives, down to the smallest motor used for street railway service, have proven definitely and conclusively that the interpole

machine is the best motor that has thus far been devised for electric railway service. However, the improvements of the year have not been confined to the interpole motors. The design of the standard non-interpole motors has been changed in various ways so that practically the only difference between the two kinds is that due to the interpoles.

The multiple-unit control with hand acceleration and valve magnets operated by line current has met with the most enthusiastic reception. The extreme simplicity of this control makes it suitable for almost any railway and its reliability makes it most desirable from that standpoint. The removal of the heavy hand controller from the platform, and the saving of all the space above the floor for the use of the passengers and the crew is another advantage; and last, but not least, is the ability to operate cars in trains. In the past year a number of very serious accidents on interurban railways have been recorded, which might have been avoided in some cases by the use of multiple-unit control. The greatest danger to be apprehended on single-track interurban lines, where a high speed schedule is maintained, is mixing up the schedule by the use of special cars or trains. This requires new passing points and additional crews, who are more or less unaccustomed to the road, and always occurs at times when travel is heaviest and crews have most to occupy their attention. The use of multiple-unit control permits the necessary number of cars to be handled in trains without adding additional trains to the schedule, and thus permits the regular crews to handle the trains, and make the regular stops and passing points. This system is much to be preferred to the use of trailers, since the use of trailers necessitates either equipments larger than necessary for the regular service and operating normally in an uneconomical manner or the overloading of equipments and running behind schedule when hauling trailers. The operation of the multiple unit control system for interurban lines will certainly be greatly extended when the value of these features is better understood.

The single-phase system possesses wonderful advantages in permitting the concentration of heavy loads at any point desired along the line. The record for heavy interurban trains is held by the Chicago, Lake Shore & South Bend Railway, which operated an 11-car train, consisting of six motor cars and five trailers over the entire line last summer. Such a feat would, of course, have been impossible on any direct-current interurban line in the country. The

year has been marked by a steady improvement in single-phase apparatus, as well as the direct-current. Improvements made in motor construction tend to make these still more rugged and reliable, while improvements in the control equipments make the possibilities for abuse of the equipments, by overspeeding, very much less liable to occur. Some of the very advantageous features of the single-phase equipment have made it subject to abuse because of insufficient safeguards to prevent overspeeding. There has recently been introduced, however, a very simple addition to the equipment, which automatically cuts off power from the motors when a certain predetermined speed is reached. It is thus possible to use over-voltage points on the control to obtain rapid acceleration to high speed, while at the same time making it impossible to operate at excessive speeds with power on.

The 1 200 volt direct-current system, which is in use on a number of interurban railways, is making steady progress. Improvements are being made as necessity demands. More breaks in series have been added to the control equipment, and better insulation for rheostats, control, etc.; rotary converters are operated two in series; 1 200 volt generators and rotary converters are being built. In general the equipments are giving satisfaction. The total cost of operating 1 200 volt roads appears to be about the same as that of similar 600 volt roads.

SOLVING NEW PROBLEMS

C. E. SKINNER

PRACTICALLY no branch of industrial work to-day can expect to make progress, or even keep abreast of the times, unless a certain amount of investigation and research work is carried out. The increasing number of research departments established as a part of industrial organizations, and the increasing number of independent laboratories established to do research work on a commercial basis, give us a good index of the attitude of the average manager of industrial corporations toward experimental and research work. Many firms not equipped with experimental or research departments are availing themselves of the independent laboratories, and even the technical universities are being used to ad-

vantage for the solution of the problems necessary to progress in industrial concerns.

Increased competition in any line of manufacture makes it necessary to take advantage of every betterment that can be made in the qualities of the materials used. Nickel steel, for example, has made possible designs which would be impossible with ordinary carbon steel. The processes of manufacture must be carried out with more exactness, since allowable variations will be less than when unnecessarily large amounts of material are used. The use of silicon steel in transformers, together with the exact processes now followed in its annealing, make possible designs which were impracticable with the older types of steel, and the variations in the electrical losses in the finished product are now exceedingly small as compared with the transformers of five years ago.

New materials must be studied and applied to meet new demands; new phenomena must be investigated and taken advantage of in new types of apparatus. The electrolytic "valve action" of aluminum-coated plates has made possible a more efficient type of lightning arrester than has hitherto been available. The best results are reached in any design when designer and shop men unite in taking advantage of all qualities or methods or phenomena that will better the character of the product. It is easy, for example, to design a steel structure which is unnecessarily strong and expensive, and nothing more than a very general knowledge of the properties of steel is required for such a design, and a poor grade of workmanship may still give satisfactory results. It is impossible to design such a structure which reduces to an absolute minimum the amount of material required to accomplish the purpose, and still be entirely safe, unless the physical properties of the best steel available are very exactly known, and to realize the proper result in the finished structure the workmanship must be of the best.

With each problem solved, a number of others arise for solution. The manufacture of a successful tungsten lamp has made it necessary to solve a host of new problems in the adaptation of these lamps, such as new reflectors and shades, new arrangements of lighting, a new low voltage transformer system, and it has been necessary to radically revise the system of manufacture of incandescent lamps. This progress has also had its effect on other types of lighting systems.

The development of material with new properties for any given class of work requires that the relation of this material to pre-

viously known materials be established. Monel metal comes to us as a new product with some properties which are different from those of the metals available for the same class of work. The intelligent use of this metal in the form of wire, rods, sheets, castings, etc., has made necessary a very considerable amount of research into its properties and limitations.

It is for the development and study of new principles, the locating of limiting qualities of materials, and the limitation of processes, that modern industrial establishments maintain research departments. Nor is the recovery and utilization of scrap and waste material a small part of the work of the research department of a well conducted industrial plant. In fact, this latter phase of the work can probably be made to show a money value more readily than any other form of research. In establishments using large amounts of copper and copper alloy, for example, the recovery of copper from the garbage furnace ashes may be sufficient to pay the salaries of all chemists employed by the company.

Instances could be given of business enterprises along established lines which, under ordinary circumstances, would be only moderately successful at best, but which have been made brilliant successes due to special care and attention to principles and details which are overlooked in the ordinary conduct of the same class of business. This research, for such it really is, usually results in the development of some specialty, for which this particular firm becomes noted, and which becomes more profitable than the ordinary line. In fact, it might be said that most industrial enterprises of today are founded on some specialty or specialties developed through investigation which may be termed "experiment" or "research". If research is not done by an organized department comprising experts along the various lines, it must be done under more adverse conditions by superintendents, shop men and others who are at the same time responsible for the production and, therefore, unable to go farther than to overcome immediate difficulties. Since advance must be made in any line where there is competition in order to sucessfully meet such competition, this can best be done by a research department, efficiently equipped, efficiently manned, and in the closest possible touch with the material supply, the principles involved in the design of apparatus, the methods of manufacture, and the commercial requirements of the finished product.

DEVELOPMENTS IN MINING AND PUMPING

W. A. THOMAS

IN the matter of power development there is a notable tendency to the development of central energy plants for mining operations, instances being the central energy plant of the Consolidation Coal Company at Van Lear, Ky., with turbo-generators, condensers and sub-station equipment; the Clinchfield Coal Corporation at Dante, Va., with the development of a 2 000 kilowatt central energy plant and four sub-stations. These are for coal mining work and represent an appreciation on the part of coal mining officials that the value of fuel is what it can be marketed for, and is a step in advance in the coal mining industry as the economics of central stations have not been sufficiently recognized in the past.

The Homestake Mining Company at Lead, S. D., is just completing a 6 000 kilowatt hydro-electric installation by diverting the Spearfish River through some 25 000 feet of rock tunnels to a canyon, thus securing some 400 feet head for the development of power. This power will be transmitted approximately 15 miles to gold mining operations.

The application of electricity to pumping has made remarkable advances, both in mining operations, municipal water works and sewage plants; installations of importance being that of the Ward Shaft Association in the old Comestock mines at Virginia City, Nev., consisting of four 250 horse-power completely enclosed motors with forced ventilation by driving air first through cooling coils, then through the motors and again through the cooling coils, the water pumped being at a temperature of approximately 175 degrees F. 2 500 feet below the surface of the ground, and the water for the cooling coils being taken from the surface at approximate 80 degrees maximum temperature. Another important installation is that of the Grand Rapids Sewage Disposal Plant, to provide against flooded conditions owing to rise of water level in the river.

A very important development of the past year has been that of small self-starting direct-current motors for isolated pumping work in and around coal mines. These motors are made with especially strong commutating characteristics, so that they can be connected directly across the line without injury, the advantage being that starting devices are unnecessary and the pumps can be allowed to run constantly; in the

event of the circuit being opened, no injury will develop when the power is again connected to the line with the motor on the circuit.

The lead of the Baldwin-Westinghouse Companies in the matter of constructing steel frame mine locomotives has been followed by others, and the past year has witnessed a great number of installations of this type of locomotive, thus reducing frame breakage to a minimum, making much stronger locomotives and permitting greater horse-power of electrical equipment on a given weight of engine.

Remarkable progress has been made in the last year in the application of electrically-driven pumps for irrigation. For instance, some 25 or 30 small pumping plants have been installed in the Columbia River Valley alone, and numerous pumping outfits have also been installed elsewhere. The most notable installation, however, is that of the Portalles Irrigation Company at Portalles, New Mexico, where a large tract of land is sub-irrigated at a depth of 25 to 40 feet. A central station plant was installed at a convenient point in this tract, where coal, mined in New Mexico, is used in gas producers to furnish gas to two 600 k. v. a. gas engine-driven generators, the power being distributed at 11 000 volts to four or five step-down stations, from which distribution is made to 72 pumps operating in wells at the proper depth to reach the water and pump it out on the land. This field of application is one of great promise.

GENERATING APPARATUS AND ROTARY CONVERTERS

F. D. NEWBURY

THE past year has not witnessed radical changes in the ordinary lines of generating apparatus. There is, however, a tendency toward higher speeds, as is evidenced by the statements here given regarding several specific sizes and types of apparatus.

Until quite recently the largest alternating-current turbo-generator built to operate at 3 600 r.p.m. was rated at 1 500 k. v. a. During the past year this speed has been used for generators up to 2 500 k. v. a., normal rating. This extraordinary capacity for a two-pole generator has been made possible by improvements in the rotor construction which allow considerably more space for copper than

was possible in older designs. The 10 000 k. v. a. turbo-generator installed by the City Electric Company of San Francisco, which operates at 1 800 r. p. m., marks another milestone in the successful building of large high-speed turbo-generators. This set was described at the December meeting of the American Society of Mechanical Engineers.

In direct-current apparatus there has been a marked tendency to supercede slower speed engine driven machines by high speed motor-generator sets in the case of alternating-current distribution, or high speed turbo-generators in the case of generators directly driven by prime movers. These developments have considerably decreased the importance of the engine type direct-current generators, particularly in railway work.

The most important change in rotary converters has been the increase in speeds of 60 cycle converters. At best, 60 cycle converters are more sensitive and require more care in operation than direct-current apparatus, with the possible exception of high speed direct-current turbo-generators. This is due almost entirely to the large number of poles necessary at this high frequency. Any increase in speed, therefore, results in a reduction in the number of poles which brings 60 cycle converters more in line with those built for 25 cycle operation. A large installation of 500 kilowatt, 60 cycle, 600 volt, 900 r. p. m. converters has recently been placed in operation by the Reading Street Railway System. Until these were undertaken, machines of this size were built with 12 poles and operated at 600 r. p. m., instead of eight poles and 900 r. p. m. Similarly the 1 000 kilowatt, 20 pole, 360 r. p. m. converters have been redesigned with 12 poles, to operate at 600 r.p.m. While 60 cycle converters are not preferable where it is possible to adopt a frequency of 25 cycles, the increase in speed has made their operation less sensitive than was formerly the case.

THE PORTLAND CEMENT INDUSTRY

C. W. DRAKE

THE past year having been a national census year, it is interesting to look back a decade upon the growth of the Portland cement industry. In 1901 it was almost in its infancy. In 1910, although the exact figures are not yet available, all indications point to a production of about 72 million barrels. The output has doubled since 1905 and has been forging ahead with an

increase of about 15 to 20 percent each year. A production of 72 million barrels, or approximately 200 000 barrels per day, is obtained only by the expenditure of a large amount of power. The common rule, which has been in use for this work, specifying one horse-power in capacity for each barrel produced per day, would indicate that on an average 200 000 horse-power had been expended throughout the past year in the manufacture of Portland cement. Just what portion of this power is applied to the machines by electric motors, it is impossible to state, but the percentage is rapidly increasing, and, in a few years, it is safe to say, engine and line shaft drive will be used in only a small percentage of the plants. Cement machinery is necessarily of heavy and rugged construction, but recently numerous improvements have been made in its design and construction, especially of the driving mechanism, so that electric motors are much more easily applicable. The question of speed and location of driving shafts has been given more consideration in the newer designs of machines. Improvements in gear reduction or in the substitution of cut instead of cast gears have been made and also improved methods of lubrication have been incorporated in the later designs. Such improvements tend toward longer life of apparatus, reduced maintenance costs and increase in the general operating efficiency of the plant.

The general tendency is towards individual drive for all of the larger machines, where large amounts of power are required, and the greater flexibility and economy is of advantage. The air in and around cement plants contains a large amount of rock or cement dust, and, althought this is not really injurious to induction motors as long as it does not enter the bearings, it is nevertheless best practice to install the motors where possible in separate rooms, with the driving shafts passing through the walls into the mill. This method of installation is used in most of the newer mills and results in a longer life of electrical apparatus with less attention and maintenance. Tube mills lend themselves very readily to this form of drive, making use of motors running at 160 r.p.m., which are connected by flexible couplings to the driving shafts of the mills. The 5 by 22 foot mill was formerly the standard, but mills of larger diameter, such as 6 or 6.5 foot, which require 150 or 200 horse-power motors, are now used. If the output is proportional to the power consumed, it may easily be seen that a large gain in space would result from the use of larger mills. It was formerly considered impracticable to use individual drive for tube mills, since

the starting torque required is very high, and it was often believed that a motor must be about twice as large as necessary to run the mill in order to start it satisfactorily. Careful attention to the characteristics of the mill have made possible the design and construction of motors which start the mills readily and run at approximately their full-load rating.

Considerable advantage is claimed by some machinery manufacturers for vertical mills and although these may be driven by horizontal motors with quarter-turn belts, the conditions have been more satisfactorily met by using vertical motors.

In general there are several characteristics required by motors for cement mill service which are common to most of the applications not only in cement mills but in similar classes of rough and heavy service. Principal among these are:—The bearings should be dust-proof; the construction of the entire motor should be rugged; the motor should have good starting torque, and the windings should not be affected by cement dust.

Although a motor should possess all of these characteristics, its operation may not be satisfactory if improperly applied. For any coupled or geared service in cement plants a flexible coupling is almost a necessity if satisfactory operation and long life are desired. When the motors are belted to the machine the belt gives the necessary flexibility and relieves the motor of any vibration there may be in the driven machine.

ELECTRIC POWER FOR INDUSTRIAL CONCERNS

J. H. KLINCK

THERE is an increasing tendency on the part of users of electric power to investigate the possibilities of central station service before installing a plant for individual use. This movement is of the greatest value both to users and those who have power to sell. Its importance has been promptly recognized by progressive central station managements, and the adoption of a liberal policy in dealing with this class of consumers has resulted in great improvement in the day loads of those central stations which have consistently followed such a policy.

Another feature is the increased interest shown by industrial concerns in the use of electrical apparatus. Instead of the haphazard installation of a motor or two to help out in times of congestion, the subject is usually considered in the broadest possible

manner. The result is that when the initial installation is finally decided upon, all details in connection with it have been carefully considered by those in responsible charge, and the lines laid down are such as are capable of being followed when the expansion, inevitable in all successful commercial enterprises, becomes necessary.

Those who begin the use of electrical energy under conditions which have been properly investigated and carefully studied almost invariably become enthusiastic in their appreciation of the results obtained, and are in themselves most powerful arguments in aiding to convert those who, while they readily admit that it is possible to see where the business of others may be thus benefited, feel that these conditions do not exactly apply to their own individual problem.

There is a marked leaning towards simplicity in connection with the distribution circuits in industrial installations. The five-wire, four-wire and three-wire circuits for power purposes have practically disappeared for direct-current power distribution, the two-wire system in connection with the auxiliary pole motor successfully meeting every demand for variable speed. In those cases in which light and power are furnished from the same circuit, three-wire circuits are installed, but the low voltage is used solely for illuminating purposes. The three-phase alternating-current circuit has become practically standard for polyphase distribution.

The application of motors to individual machines has been increasing, especially in the metal-working industries. The successful development of high speed cutting steel has rendered the introduction of new types of tools desirable, and manufacturers have been quick to realize the possibility of obtaining increased output by carefully proportioning tool and motor. Recent designs show greatly increased strength in the tools themselves, marked simplicity in general appearance and considerable increase in the rated output of the motors used to operate them. The control of the larger motors demanded for the operation of individual machines has received considerable attention, resulting in an increased field for automatic starting and controlling devices. Recent installations of apparatus of this type have been very successful.

As a whole, no decided changes in the application of motors for industrial purposes have been observed during the past year, those which have been made being along the broad, general lines which mark the steady improvement characteristic of all established commercial activities.

NOTES ON TRANSFORMER DEVELOPMENT

W. M. McCONAHEY

In transformer design much has been accomplished during the past year in the way of developments and improvements. Among the large transformers there has been a demand for units of higher voltage and greater output. The distances that electrical power can be transmitted without excessive loss in the transmission line or excessive cost depends, up to a certain limit, almost entirely upon the voltage. The most economical source of power for developing electrical energy lies in the great waterfalls of the country, but many of these are so remotely located that they cannot at present be made use of for this purpose, while others not so remotely located are being developed and electrical power is being transmitted over much longer distances than would have been attempted a few years ago. From this it is seen that the tendency is steadily toward higher transmission voltages and one of the problems of the transformer engineer is to foresee and anticipate the demand and be able to meet it when it arrives. A number of systems are now operating successfully at 100 000 and 110 000 volts, and before another year has passed by there will, in all probability, be at least one system operating at 140 000 volts with ungrounded neutral.

With increasing voltages there naturally comes increase in size. The higher the voltage, the larger the minimum size that can be built economically. There are also other good reasons why a few large transformers in a station are better than a larger number of smaller ones. Among these reasons may be mentioned, less total cost, less floor space, better performance, less chance of breakdown because of the smaller number of units and simpler wiring and switching arrangements. These advantages are being appreciated more and more, so that the tendency is toward the use of larger units. A few years ago the largest transformers used did not exceed 2 000 to 2 500 k.v.a., while now, single-phase transformers of double that size and three-phase transformers up to 10 000 k.v.a. are in use.

Large three-phase transformers have been in general use in Europe for a number of years, but it is only very recently that they have been built in this country. A three-phase transformer occupies less space than an equivalent bank of three single-phase, is slightly more efficient, and the arrangements of wiring and switching are more simple. The disadvantages are: The considerable weights of

the large sizes, which make handling difficult in many cases, the increased time and cost of making repairs, and the cost of a spare, if one is kept for emergency. The advantages of using three-phase transformers in many cases are being recognized in this country, and this type is coming more and more into use.

Undoubtedly the most important transformer development of the past year has been that of the new self-cooling transformer of large size. Heretofore the limit of size for a self-cooling transformer was about 800 k.v.a., or possibly 1 000 k.v.a., for comparatively low voltages, but the limit of the new type is from 2 000 to 3 500 k.v.a., depending upon the voltage and frequency. Self-cooling transformers require no attention other than occasional inspection and can be placed in stations where water-cooled transformers could not be used because of the lack of water or its excessive cost. Consequently there is a wide demand for large self-cooling transformers.

The problem of designing self-cooling transformers of large capacity is simply one of designing a tank with sufficient surface to radiate the heat generated in the transformer and keep the temperature rise within the necessary limits. The amount of surface depends upon its efficiency, which may be defined as the watts radiated per square inch of surface, as well as upon the amount of heat to be radiated. A plain surface is the most efficient, but as it is broken up into corrugations, the efficiency decreases. At first the increase in surface is much more rapid than the decrease in efficiency, but as the surface is broken up further and the depth of corrugation increased, a point is reached where the efficiency begins to decrease very rapidly, and beyond this point it is useless to go, as nothing further can be gained by increasing the depth of corrugation. In the new type of case, however, a method has been found whereby the surface can be very largely increased and at the same time the radiating efficiency of the surface kept very high. This method consists simply in fitting the outside of a boiler iron tank with a large number of vertically arranged tubes, the upper ends of which enter the tank near the top and the lower ends near the bottom. The tubes stand out well from the sides of the tank so that the cooling air can circulate freely among them. Since the efficiency of the cooling surface depends very largely upon the ease with which the cooling air can pass over it without being impeded by restricted passages, or air pockets, it is readily seen that this type of tank for large self-cooling transformers is far in ad-

vance of any other type that has ever been proposed. It stands by itself as the only practical type in use.

Locomotive auto-transformers, which were first built in capacities of about 500 k.v.a., have been steadily increasing in size, and recently transformers of this type have been used on the New York, New Haven & Hartford Railroad of 1 500 k.v.a. capacity. Railway auto-transformers are in a class by themselves, on account of the peculiar conditions under which they work and the hard service to which they are subjected.

Among the smaller transformers, generally known as "distributing," the present type occupies an enviable position due to its high quality and splendid performance. Superior design, material and workmanship are responsible for this. During the past year, only a few minor changes of small importance have been made, the aim being to take advantage of every improvement, no matter how small, that could be suggested.

Supplementing the ordinary distributing transformer, there have been brought out during the year a line which is of the same high quality, but wound for high-tension voltage of 6 600, 11 000 and 16 500. The increased number of systems employing these voltages has created a demand for this line.

Three-phase transformers in commercial sizes up to 50 k.v.a. are now available and meet with favor, as it is generally more convenient to use a three-phase transformer for local three-phase distribution than three single-phase units. This is appreciated more than formerly and the demand for three-phase transformers of this type is rapidly growing.

Research and experimental investigations covering the various phases of transformer work have been carried on continuously and the information obtained thereby has been applied in keeping the transformers up to the highest standard of excellence.

PROGRESS IN DETAIL APPARATUS.

T. S. PERKINS

THE general tendency in detail apparatus during 1910 has been to develop to a higher degree of perfection existing lines of apparatus, so as to obtain greater accuracy and durability, and to make modifications and extensions, so as to better adapt the apparatus to specific applications. For convenience detail apparatus will be considered according to the following classifications:—

Measuring apparatus; protective apparatus; control apparatus; lighting apparatus; fan motors, and cooking and heating apparatus.

Measuring Apparatus—The general tendency in measuring instruments has been toward the use of permanent magnet types for direct-current work and induction types for alternating-current work. The permanent magnet types have been improved principally with a view to accessibility of parts for repairs. The D'Arsonval types are now made so that they can be completely removed from the meter case without taking the magnets off the pole-pieces, or otherwise disturbing the magnetic conditions. The single air-gap construction of the permanent magnet meters is the result of the above considerations. Shunts of interchangeable drop are furnished for these instruments. Induction type meters have been greatly improved during the year so as to make them dead beat and higher in torque without increasing the weight of the movement.

In switchboard instruments the tendency has been toward round open dial meters instead of cases having glass only over the scale portion, thus obtaining better illumination and greater readability from a distance. Among specific cases of developments are the following: Improved relay type of graphic meters with motor-wound clocks; the iron loss voltmeter for use in testing transformer losses; a relay for alternating-current reverse current transmission line work; static voltmeters for high tension measurements up to 300 000 volts. In watt-hour meters the tendency has been to still greater accuracy, permanency and convenience in handling. The year has seen practically universal adoption of the rotating standard method of testing service meters. Other important developments bearing on these meters are the adoption by the National Electric Light Association and by the Edison Association, of a joint meter code, and supervision by Public Service Commissions created by State Legislatures.

Protective Apparatus—The increase in the capacity of generating stations and the resultant magnitude of the currents that can be fed into distributing lines in case of short-circuit has made the circuit breaker problem one of not only great importance, but also one of the most difficult in the electrical industry. There has been considerable done on this problem and developments are under way, which give promise that

this kind of apparatus will keep pace with the requirements. Circuit breakers better suited to use for the protection of induction motors have been developed. On railway circuits there seems to be a growing tendency to use fuses in addition to circuit breakers. In lightning arrester work the year has seen the perfecting in detail of the electrolytic or aluminum type of arrester and its general application to power circuits. A tendency is manifest, however, to reduce static protective apparatus to simpler, less expensive and more rugged forms. The demonstrated strength of oil transformers has, in the minds of many engineers, warranted this. There is also a manifest tendency to put high voltage sub-station apparatus out doors. The lightning protective devices have led the way in this departure and for all voltages types can be found suitable for outdoor use.

Control Apparatus—The demands for control apparatus, covering the year 1910, have shown a tendency in all lines, leading toward the higher perfection of design, wider application, more automatic operation and more protection to operator and apparatus. In motor starting apparatus operated by hand the tendency, especially in larger sizes, is toward unit switch construction. In field control apparatus there has been more call for remote control in applications along industrial lines, such as paper mill and printing press control. Along the line of automatic control there has been considerable activity. The effect of an automatic control, such as is operated by a master switch or controller, is to insure uniform and proper operation, thus protecting expensive machinery and necessitating less experienced operators. Employment of dynamic braking has become more general, and there has been marked activity in control of alternating-current motors. No voltage and overload protection for auto-starters has also been introduced and is being widely applied.

Electric Lighting Apparatus—There has been a marked tendency toward a more general use, as well as more scientific application, of high efficiency lamps. The advantages of the higher efficiency units have fallen largely to the consumer, but the central stations by an active enthusiastic campaign for higher standard of illumination have kept up their station output. There has been a decided tendency toward improvements in exterior illumination. The field where lighting is least used in proportion to its possibilities is in street, park and boulevard light-

ing. Very considerable activity has been manifest in promoting higher standard of street illumination in this country. It is fortunate that the field in which a higher standard of illumination is most needed is also one in which any improvement attracts greater attention. The campaign for the education of the public to a higher standard of street illumination has been encouraged and assisted by the introduction of larger illumination units. The use of the series tungsten system for street lighting has been rapidly extended. There is a very considerable field where this system can be properly used, and it seems to be coming generally recognized that such is the case. While no material improvements have been made in the constant current mercury rectifier for the operation of arc lights yet its use has become demonstrated as commercially satisfactory in every way and likely to be standard for some years to come. Its use for battery charging has continued to increase.

Fan Motors—The use of fan motors continues to grow rapidly. The improvements of the year have been along the line of perfecting details to get economy of current consumption, large volume of air moved, wide zone of air distribution, quiet operation, minimum attention on the part of the user, speed regulation and long life. Attention has particularly been directed toward improving appearance and reducing the weight.

Cooking and Heating Apparatus—The field for this apparatus is extending rapidly. There has been considerable activity in developments along broad lines. Some new appliances have been made and others will follow rapidly. An important example is the completion of a boiler for generating steam on a locomotive for heating passenger trains. The tendency in industrial and household appliances has been to create designs which bring the heating element in closer contact with the thing to be heated. For instance, in the water heater, the heating element is immersed in the water instead of placing a vessel containing the water on a heated surface. This results in a material gain in efficiency. Other applications of the idea are in coffee percolators, chaffing dishes, frying pans, soldering pots, glue pots, etc.

A CONVERSATION ON AMERICAN AND EUROPEAN RAILWAY PRACTICE

CHARLES COLLETT

HERR GRÜNDLICH had been visiting this country in order to study American railway practice. He had investigated practically every large railway electrification and many street car systems. Consequently I was interested in obtaining from him an expression of his views in regard to American methods, which he would most naturally compare with European electric railway practice. Although I knew him as a progressive engineer, this was my first opportunity to informally discuss with him the many problems in which we were both so actively interested. It was on the evening of his departure and we had proceeded to the dining-room at the station. I found him quite ready to talk and accordingly my questions were many and varied.

"The European engineer," he said, in reply to what was, of course, my first query, "upon arriving in this country for the purpose of learning something about American methods in electric railway engineering, is at first impressed, in general, by two characteristic features, namely, the higher speeds maintained throughout the entire field of electric traction and the heavier loads hauled on American roads. Heavy loads are particularly characteristic of electric locomotive service, and the statement applies also to car operation. As a result the capacities of the individual motors are generally larger, especially in the case of street car equipments."

"I believe," he continued, "that American interurban electric railways have had a development which may never be equaled in Europe. The quality of man employed in railway operation is superior as far as resourcefulness and quickness is concerned, but inferior as far as discipline and instruction regarding economical and safe operation goes. Moreover the maintenance of the entire system is poorer, particularly in the case of rolling stock, and from the coal pile up there seems to be greater waste."

While I was compelled to admit that his points were well taken, I emphasized the fact that the present tendency in America is strongly in the direction of greater economy.

"As regards operating speeds," he continued, "you will note than in most countries where the steam railroads are owned by private companies, the speeds are higher than in countries where government ownership exists. Higher speeds will always appeal to the traveling public at large; consequently this feature is used as a most important advertisement, especially where several roads are

competing. The large distances between important business centers are also responsible for the higher schedule speeds used on American steam trunk lines. This tendency, due in no small degree, I presume, to the public demand, has come to embrace electric traction in general. Thus, you see, it is natural that in America higher speeds are maintained throughout. The speed problem has practically been solved as far as the capability of the electric motor to propel trains is concerned. The problems which at present confront the engineer are more the mechanical design of the rolling stock and the question of securing a roadbed and rail construction which will withstand the strain of heavy loads and high speeds with a large margin of safety. Germany, and in fact nearly all continental Europe, is more handicapped in regard to speeds. The roads that were built in the early days of steam locomotive operation were laid out to connect as many cities as possible. This was no doubt economical in those days, considering the traffic and speeds used, but it was not farsighted and today these very facts offer problems which, as the population becomes denser, will be more and more difficult to solve. In fact, such radical changes as the rerouting of roads would seem almost impossible, in most cases, on account of the enormous expense involved."

"And you say that European trains are not as heavy as in this country?" I questioned.

"Yes, the average weight of trains will be found in most cases to be somewhat less and in the case of freight trains the reason will be apparent. In this country the weight of trains is limited by the strength of the drawbar, while in Europe the weight is limited ordinarily by the length of the train. The permissible weight per axle is invariably much lower in both passenger and freight service. Consequently, freight trains of weights such as I have observed to be common in the West would hardly be possible in Europe on account of their length, which, in turn, is primarily limited by the size of freight yards. As you know, the individual passenger cars used abroad are lighter, but at the same time the weight per passenger is less. Accordingly, such powerful engines as are used on American roads are not required in Europe, unless to a limited extent in mountain service."

Our conversation drifted from generalities to engineering details, and I asked him if he would not tell me more particularly wherein European practice differed from what he had observed in this country. As a result of his study, Herr Gründlich had appar-

ently developed a profound admiration for American electric railway engineering and was unbiased in his views regarding good engineering, as an engineer ought to be. He said that he was glad, however, to avail himself of the opportunity to point out some features of European practice which, with due consideration of relative conditions, he thought superior to American ways of doing things.

"Being particularly familiar with German practice," he explained, "what I say will refer mainly to German standards, and to start at the bottom, I might first mention rails. The rails used in Germany on main trunk lines generally weigh from seventy-five to eighty pounds per yard. Lately, however, rails of one hundred pounds and more have been introduced. The ties are laid with greater spacing than in this country, but on the other hand, tieplates are applied much more generally and, instead of spikes driven into the ties, it is Prussian government practice to use tie screws. Spikes are never used on main trunk lines. A rather peculiar difference is the fact that in Germany the rail joints are not staggered but are on the same tie, and the joint proper is placed midway between ties so as to give sufficient flexibility. While there seems to be no doubt as to which of these represents the better engineering, nevertheless, the same practice is followed in most of the countries of continental Europe."

"The specifications for the rail manufacturers are somewhat more rigid in Germany than in this country insamuch as they are compelled to scrap more of the crop of the ingot, a practice which, no doubt, is responsible to a great extent for the comparatively few accidents that occur due to broken rails. The rails used in street car operation vary a great deal in weight, size and crossections.

"The so-called girder or step rail which is used so extensively in this county, is not found in Germany. This design of rail certainly seems to have more disadvantages than advantages as a street rail. While the general tendency abroad is to divert all heavy haul wagon traffic from the street car tracks, the girder rail wherever it corresponds to wagon gauge will attract this traffic by virtue of its very design."

"Yes, but you must understand that this type of rail has been forced upon the street car companies in several localities purposely to assist heavy wagon haul on hilly roads, or otherwise in lieu of good pavement."

"While their use in suburbs where the service is infrequent may seem justified," said he, "girder rails should not be used in city streets where cars follow each other in quick succession. It is a common occurrence for heavy wagons using the rails to experience difficulty in getting out of the tracks. The girder rail in congested thoroughfares is a great impediment to good street car service."

It occurred to me just then that Herr Gründlich might have some interesting comments to make with reference to electric locomotive design and I questioned him accordingly. I mentioned the early Baltimore and Ohio locomotive, which today stands as the American pioneer for heavy railway service.

"It is my impression," he replied, "that the electric locomotive has had practically the same evolution in Europe as in America. First appeared the single truck locomotive with a short, rigid wheel base, equipped with one or two axle-hung or gearless motors. Then came the double truck locomotive equipped with two or four axle-hung motors, the frame being strong enough to transmit the drawbar pull, examples of which are the first Valtellina and the early type of New Haven locomotive. Developments of this type are the Detroit Tunnel and Great Northern electric locomotives which use articulated trucks. The gearless motor has hardly passed the experimental stage as far as continental Europe is concerned. Since the motors have been lifted out of the cradle that has held them so long, the designs have become more varied and numerous. While two or three years ago the bone of contention in the United States was whether single-phase or direct-current was best suited for heavy electric traction, the Ganz Company, of Budapest, and a few other firms, realizing the advantages of a higher center of gravity, made a decided change in the prevailing design by introducing a running gear with side rods; a point of design which, at the time, was considered in this country a decided step backwards—as far as I could judge from the technical press."

"In spite of that," I interrupted, "it was left to this country first to design and build electric locomotives with side rods and jack shafts, thus closely following steam locomotive practice. The machines to which I refer are the large articulated locomotives built for the Pennsylvania Railroad. And the idea of obtaining a higher center of gravity was one of the factors influencing the design of the later four-motor New Haven passenger

and freight locomotive in which each of the motors is mounted above its driving axle, to which it is connected by flexible gears."

"Yes," said my friend, who had evidently been impressed by the design of this latter machine, "this is a noteworthy design of locomotive; it embodies all essential features necessary to give good riding qualities, with an efficient drive. It seems strange," he remarked, "that so many prominent engineers, both here and abroad, have so little faith in gears for heavy traction. Gears made of first class material, carefully machined and used in connection with a flexible drive, such as is embodied in these locomotives, should show very satisfactory wearing qualities and give excellent results."

"It seems to be the general opinion," he commented, "that the good results obtained with side rods in steam locomotive operation will be duplicated in the case of electric locomotives with siderods and jack shaft. This may become true, but while in electric locomotives the action of the piston rod inherent with the steam locomotive has been eliminated by connecting the driving rod directly to the crank on the motor axle, other forces are introduced by the jack shaft which may give rise to difficulties. Yet it is too early to pass any decided opinion on this matter. A year's operation may reveal interesting facts. Nevertheless, the side rod type of electric locomotive with jack shaft seems to have come to stay. The tendency in Germany and northern continental Europe is at the present time in the direction of concentrating the power of the locomotive in one or two large motors which transmit their power directly to the axles by means of jack shafts and side rods. In Italy and Switzerland where three-phase locomotives—admirably suited for mountain service—have scored a remarkable success, a somewhat different running gear with Scotch yoke is employed. The bogie truck, although used extensively in American designs, is seldom found on European electric locomotives, while the pony truck is deemed sufficient as a leading truck."

"I do not know," he continued, "whether you have noted a characteristic difference in the mechanical construction of American and European locomotives. Here I find that the frames of the locomotives are generally of cast steel, while abroad only structural steel is used. An exception to this is to be found in the locomotives built by the well-known firm *Maffei* of Munich, Bavaria, which has followed American practice in using cast steel frames. Cast steel is cheaper but heavier, and it is mainly because

of its greater weight that Germany has resorted to structural steel frames, as the government has specified a maximum allowable weight of only 15 tons per axle for railroad equipments. It might be expected that the introduction of heavier rails would raise this figure, but such would hardly be the case as the maximum permissible load per axle is largely governed by the bridges."

"Is not the multiple operation of electric trains common practice abroad?" I asked.

"In Germany and England particularly," replied Herr Gründlich, "you will find that, in the electrification of steam roads up to the present time, multiple-unit trains have been favored in preference to electric locomotives, while here multiple-unit train operation has thus far been confined mainly to subway and elevated service. While the rolling stock available from steam operation cannot be used to such an advantage in multiple-unit trains, this is offset by the fact that higher acceleration is possible than with electric locomotives, and in reversing the direction of trains, no switching of locomotives is necessary."

"The problem of increasing the capacity of existing tracks repeatedly presents itself, and electric operation of trains is the only solution where further improvement with the steam locomotive can not be effected and the laying of additional tracks is prohibited by local conditions or too great expense is involved. I have taken considerable interest in analyzing problems of this kind," he confided. "The solution is based primarily upon the closer headway of trains possible with electric operation. The problem becomes more and more difficult, the greater the number of stops for a given schedule. The length of time required by trains to traverse stations has by far the greatest influence upon the headway when the stops are frequent. For our purpose we may define the station as the section betwen 'In' and 'Out' signals. You will thus see that the time required by trains at stations is governed by the duration of stop which may be assumed as fixed, the time required for braking and that required for acceleration. With electric operation the time required for the retardation of trains can be reduced by electrically operating the brake release valves, and a constant rate of braking of even one meter per second per second (equivalent to two and one-quarter miles per hour per second) can be obtained with certainty. The time used in accelerating trains is, of course, also dependent upon the rate of acceleration

obtainable, in view of which multiple-unit operation offers a great advantage."

Then Herr Gründnlich cited a specific case, that of the "Berliner Stadtbahn," which at the present time is operated by steam with three-quarter coupled compound locomotives, and which maintains a headway of two and one-half minutes as the very best time possible. On account of the increasing traffic and the difficulty of building additional tracks, the electrification of this entire system has been contemplated for several years.

"Well, why don't they do it?" I thought, but I did not interrupt him.

"Consider now," said he, "that the use of multiple-unit trains would make it possible to decrease the headway from two and one-half minutes between trains with steam, to one hundred seconds—a gain of thirty-three and a third percent!"

He then enumerated the conditions on which this decrease of headway was based:—First, distance between In and Out signals at stations to be 305 meters (1 000 feet), it being possible, however, to shorten this to 200 meters (657 feet); second, present block signals to be used as they stand; third, a rate of braking of 0.75 meters per second per second (1.68 miles per hour per second); fourth, a rate of acceleration of 0.5 meters per second per second (1.12 miles per hour per second); fifth, average time of stops twenty-five seconds, and sixth, time for actuating the signals ten seconds, although only six seconds are required. He then proceeded to explain how the introduction of electric service would increase the capacity of the present tracks for handling passengers, and as he talked he drew from his pocket the following interesting clipping from *Electrische Bahnen und Betriebe:*

Train Data	Improved Steam Locomotive Operation	Ultimate Operation With Multiple Unite Electric Trains
Headway	$2\frac{1}{2}$ min.	100 Seconds
No. per Hour	48	72
Seating Capacity . .	10 cars, 476 seats	4 Motor Cars and 6 Trailers, 602 seats
Length	124 meters, (407 ft.) including loco.	147 Meters (482 ft.)
Weight and Full-Load	280 Tons (incl. 62.2 ton loco.) Loaded 36 percent above seating capacity	345 Tons. Loaded 58 Percent above Seating Capacity.
No. of Passengers per Hour	22 800	43 200
Possible Increase in Capacity (percent)	0	89

"Thus, you will see, that even with the most improved steam locomotive operation, the introduction of electric service offers an increase of almost ninety percent in capacity for handling passengers without increasing the number of tracks. Incidentally, considerable increase in schedule speed would be obtained, which in turn would necessitate less rolling stock."

"Do you find that the cars used in multiple-unit trains in this country and Europe differ materially?" I asked.

"Oh, yes," replied Herr Gründlich, "each country seems to follow the types prevailing under steam locomotive operation. In Germany, England and France, where cars with individual compartments and side doors are used on steam roads, this type of car has held its own for multiple-unit trains. A departure from this type was adopted by the subways and some elevated roads, particularly in England and France, where the influence of American design was very pronounced, as evidenced by the fact that the coach type of car was adopted. In subways and on elevated roads where it is necessary to prevent people from boarding or leaving trains while in motion, the coach type of car, with gates at both ends regulated by a guard, is, in my judgment, very safe and efficient for handling large crowds; particularly, the design with two additional doors, one on each side at the middle of the car, as this arrangement makes it possible to direct the entering and leaving of passengers."

"However, speaking of rapid transit in general, whether the trains be multiple-unit or hauled by electric locomotives, there is no question in my mind as to the greater ability of the compartment car than the ordinary coach type used in America, for handling large crowds with minimum time for stops. The cars I refer to are the type which is used on the Berliner Stadtbahn. As you doubtless know, these cars are divided into eight or ten compartments. Each compartment has a door at each side and an aisle on one side the entire length of the car, which facilitates the distribution of passengers and thus prevents overcrowding of any one compartment. All doors can be opened from both the inside and outside, but the general discipline, enforced by imposing fines, is such that no one tries to board or leave a train while in motion save American tourists who are ever in a hurry to get there," said he, with a laugh.

"Would not a further improvement in the distribution of pas-

sengers be obtained by providing doors at both ends of the cars, as in the coaches in this country, and do you not consider having two different classes of cars in suburban and city service a drawback?" I asked.

"Yes, interconnecting the cars through the use of vestibules would be an improvement, but this is not as essential as with the coach type of car, because, with the compartment car used abroad, the traveling public distribute themselves more evenly alongside the entire length of trains at stations. In regard to the different classes of cars, I believe that for all short haul service single class cars are to be recommended. On several occasions during my visit to this country I have observed how slowly the ordinary coaches are emptied. I asked myself, what happens in time of accident in these coaches and Pullman cars where there are only two doors and where the windows are so designed that no normal person could get out by way of them? I have been told that the reason for building the windows in such a manner in this country is mainly to prevent people from leaning out of them, an act which is rendered especially dangerous on account of the smaller distance between adjacent tracks than is used abroad."

"This drawback of having only two doors on each car, the German Pullman cars have in common with the cars in this country. You may be interested to know, however, that after certain accidents which occurred several years ago where passengers, unable to force their way through the doors and windows, had been burned to death by fire or escaping steam, a commission appointed by the government to investigate the matter and find a remedy decided to specify various changes in the prevailing design. These consisted mainly in making the windows considerably larger, particularly in width, reënforcing the window frames and attaching grab handles on the outside of the car body near each window to facilitate exit in case of accident."

I assured Herr Gründlich that these comments interested me greatly and that one could not but admire the thoroughness with which details that affect public safety are regulated abroad. "But," said, I, "you have not given me your impression regarding what you have seen of American street car practice. Do American methods differ greatly from those abroad?"

"America is unquestionably the leading country in the use of double truck street cars," he replied. "While in Germany the

double truck car is gaining ground, the single truck car is by far in the majority. Trailer cars are used to a much larger extent than in this country; they are usually detailed for 'smoker' service. The double decker, common in England, has been altogether abolished in Germany in the few places where it was used. The motor cars are of a lighter design; that is, the weight per seat is less than in American cars. Because of the smaller and lighter cars the total motor capacity is smaller. While the motors found in Germany may have slightly higher efficiencies, it is doubtful if they would stand the wear and tear and overloads that I find motors, particularly on street cars, are subjected to in this country."

"The undercutting of commutators has given good results and this practice is becoming more and more prevalent abroad as well as here. In Germany cast iron is ordinarily used for grid resistance, while in this country alloys are used, chiefly for the purpose of gaining greater strength."

"I note that in this country it is still customary in street car service to make stops at all streets. This practice has been almost entirely abandoned in Germany, where cars stop only at points designated by signs. How far apart to place these signs is a study and is entirely dependent upon the local conditions. Superfluous stops are eliminated, while the majority of people are served equally well. The practice thus offers an economic advantage and consequently is being adopted more and more generally."

"The noise of street cars in most American cities is rather marked as compared with those of Europe, a fact most probably due to the generally heavier cars used. To minimize noise, a first-class road bed is essential, beside a form of truck construction which will minimize resonance. Various designs of trucks and car bodies may be found abroad in which vibration is materially reduced by the judicious insertion of damping material in the frames."

"I find that the control equipments are essentially the same here and abroad. Switches built in units—what you call 'switch groups'—have not been used abroad. The contactors are usually mounted separately and thus require more room. Although the control equipments may be cheaper, more wiring is required and the connections, therefore, become complicated. All contactors are operated electro-magnetically and only with line current."

"What sort of results have been obtained with switches oper-

ated by electro-magnets in heavy locomotive service?" I interrupted.

"Experience seems to indicate," he answered, "that the forms of electro-magnetically operated switches generally used work satisfactorily up to approximately one hundred and fifty amperes, as a large surface of contact is not needed. With larger currents, however, greater contact pressure is required, and to obtain this, the pull of the magnet can be magnified by a lever arrangement acting upon the contact. To reduce the influence of the variable line voltage a very high flux density is used in the magnet core. Notwithstanding comments to the contrary, however, I consider that switches of the electro-pneumatically operated type are most eminently suited for locomotive equipments, particularly where heavy currents are involved. The exceedingly strong springs used in opening the switches serve to eliminate entirely the possibility of freezing together of the contacts."

"You will find that on all equipments of European design," he continued, "the high-tension control apparatus is concentrated in a fool-proof compartment; that is, one which cannot be opened unless all connections to the live line are broken. Transformers of the oil insulated, core type have thus far invariably been used on locomotives as well as cars. The shell type transformer, which is the only type feasible for air blast, and which you have employed with such general success in this country, has not been used as yet in Germany."

"What is the most marked practice abroad as regards the design of current collectors?" I asked.

"While the wheel trolley seemingly has conquered the entire field of street car operation in this country," he replied, "the bow trolley is employed most commonly in Germany. Attempts have seldom been made to use the wheel trolley for speeds above forty kilometers (twenty-five miles) per hour, and I have been greatly surprised to find various roads in this country operating satisfactorily with wheel trolleys at speeds considerably higher than this. In any event, I am certain that the wheel trolley is out of the question where a headway of less than two hundred seconds has to be maintained, for the effect of interruptions is accumulative and thus the continuity of service of an entire system may become involved in the seemingly minor mishap of a trolley leaving the wire.

"Aluminum is used to a great extent for bow trolleys. Their life in street car service is from seven thousand to ninety-five hun-

dred miles, with speeds up to thirty kilometers (19 miles) per hour. This mileage is obtained through good maintenance, that is, by keeping the running surface of the shoes in good condition with wooden files."

"Various types of pantagraph and bow trolleys are used for single-phase equipments in Germany. The most important condition to be satisfied by a good high-tension current collector is that it shall always be in contact with the line whatever the speed. To obtain this it is necessary to keep the inertia of the moving parts which touch the trolley wire as small as possible. It is, therefore, customary in Germany to use two movable parts, one which adjusts itself according to the average height of the trolley wire and another that follows the small irregularities in the wire."

"To solve the problem of current collection at high speeds," I said, "is a comparatively easy matter as far as Europe is concerned. While in Germany the normal height of the trolley wire above the rail on trunk lines is, I understand, about seventeen feet, the height varying from approximately seventeen and three-quarter down to fifteen and three-quarter feet, the maximum and minimum heights in this country are approximately twenty-two and fifteen feet respectively. "Thus," I pointed out, "in Germany the maximum variation that has to be met in the design of current collectors is about two feet, while in this country the current collectors have to operate within as wide limits as six to seven feet. A height of twenty-two feet above the rails has been required on trunk lines, due to the American custom of signaling freight trains from the tops of the cars.

"Well, under these conditions I readily appreciate the greater difficulty encountered," said my friend, "but even now that I know the reason, I do not see why it should be necessary to *hold* to this method. A reduction in the height of the trolley wire would not only diminish the maximum variation but would allow of lighter, less elaborate and therefore less costly overhead construction."

"You may be interested to know that Siemens used the first catenary type of line construction in the year 1888, on a line between Frankfurt and Offenbach," observed Herr Gründlich, "and for many years this was the only case of its application. However, it again made its appearance with the introduction of the single-phase motor. The catenary construction in Europe differs but little from the types adopted in America. The principle upon which the designs are based is essentially the same, that is, to improve

current collection by making the trolley wire self-adjustable vertically in order to meet the trolley shoe half way, so to speak."

"An additional feature which further improves the contact between trolley wire and shoe and makes it unnecessary to adjust the trolley wire with change of temperature is the method of installing the wire in standard lengths, dead-ending it at one end of each section, and weighting it at the other end so as to maintain constant tension. The sections are so installed that, with normal direction of running, the pull of the trolleys will be in the same direction as that of the weights. The sections of wire are manufactured in one piece; thus the unsatisfactory method of soldering on the line is avoided, and incidentally this method of dead-ending serves as a section break as well. This construction has been successful in the few cases in which it has been used."

"Are the high-tension current collectors raised against the trolley wire by means of tension or compression springs and lowered by compressed air, as is customary practice here?" I asked.

"No, the reverse principle is used, at least in Germany. There," he proceeded to explain, "the high-tension current collector is raised and held by compressed air. If for some reason the air pressure goes off, the current collector is automatically lowered. But, while the air raises the trolley into position, springs supply the necessary pressure against the trolley wire. A pressure of seven pounds is generally used. Sometimes a slightly greater pressure is employed, but eleven to twelve pounds is considered too high on account of the resultant heavy wear. The contact shoe itself is generally of U-shaped cross-section and made of aluminum or composition metal. Its weight is kept within three and one-half to four pounds. For lubrication graphite placed in the U has given good results. The life of the shoes with speeds up to about seventy-two kilometers (forty-five miles) per hour is seven to nine thousand kilometers (forty-five hundred to fifty-six hundred miles). The maximum permissible current per shoe has been found in service to be approximately one hundred and fifty amperes. With aluminum shoes no sparking is permissible on account of the excessive wear due to pitting. Therefore, with aluminum shoes two pantagraphs are required. There is a disadvantage in the use of aluminum which is avoided by the use of suitable alloys, namely, that it is liable to melt through whenever a heavy ground occurs on the locomotive or car. To distribute the wear on the shoes the trolley wires are supported in zigzag lines."

"There is another point," he added, "which is worthy of consideration in connection with city electric line construction and to which much attention has been given abroad, as you doubtless have noticed in the technical press. Wooden poles are rarely used. Attractive designs of round iron or lattice work poles are common, and in the larger cities a further improvement is obtained by carrying the trolley lines and the street lighting on the same poles, in order to eliminate the unsightliness of a multitude of poles such as may be found in many American cities where this matter is not taken care of by the lighting and railway companies, either of their own initiative or through action on the part of the municipal authorities. In Germany, for instance, companies desiring city franchises are required to submit to the authorities detailed designs of poles which they propose to use on their systems; or, in some cases, an approved design is specified."

"You have found the question of electrification of steam roads in this country a very live subject, Herr Gründlich," I ventured. "I should like to know what you consider to be the prevailing attitude abroad toward electrifications, both present and prospective. For instance, which system is most generally advocated?"

"But these are such broad questions," he protested. "Yet I can say that nearly all influential railway officials and prominent engineers have long realized that eventually the electrification of steam roads is bound to come. Germany, Italy, Switzerland, France, England and Scandinavia have made a good start, and most of the countries interested recognize the absolute necessity of standardization to some one universal system, if electrification on a large scale shall be possible and economical. Greater economy of operation will of course be possible through electrification, particularly in those countries where the cost of coal is high and extensive sources of water power are available. But for those countries which are less fortunate in regard to water power resources many advantages remain to be realized, such as the improved facilities for handling increased traffic. This is illustrated in Germany, where, although water power does not abound, coal is fairly cheap, and the traffic conditions are such as to render maximum efficiency of operation a matter of necessity."

"In questions involving radical changes in present conditions, whatever the character, Europe manifests considerably greater inertia than America," observed Herr Gründlich. "One should always remember that in Germany, for instance, the natural resources

and the growth of the population are fairly well known. This in itself leads toward economy in expenditure of money and the protection of human lives. Hence, the general adoption of changes of far-reaching scope may not be deemed justified after the questions have been studied in detail, in the experimental stage. This policy serves to forestall expensive and sometimes even extravagant service tests."

"Note, as a specific case, that it is more than seven years ago that the high speed tests with large three-phase cars were made on the Berlin-Zossen line. The results were satisfactory and speeds were attained which never had been reached before. The technical press predicted that the day of large electrifications had begun. But it did not develop thus. While the elaborate tests on the Berlin-Zossen line were conducted by the government for the purpose of carefully studying the merits of the three-phase motor, current collection at high speeds, effect of train resistance, cost of operation, beside the study of car design, roadbed construction, etc., one of the most salient factors of the investigation was the question—'What speeds can be obtained with the greatest possible safety to the traveling public?' And in the meantime, investigations have continued."

"During which time," said I, in defense of American methods and enterprise, "there have been many foreign engineers in this country, sent here by government and private interests to study the numerous engineering projects that we have put in actual operation during this same interval of time."

"But, in the eye of the European engineer, America is the land of unlimited resources," he replied, "and could afford to undertake its preliminary work in the commercial development of electric roads on a much larger scale, and Europe has materially benefited by the experience gained. It is significant, in view of these facts, he continued, "that, at the present time northern continental Europe looks upon the single-phase system as the most satisfactory solution for trunk line electrification."

"Train for Philadelphia, Washington, New York and points East," interrupted the monotonous voice of the train caller.

"Well, Herr Gründlich, I am glad that you can take with you a good impression of American transportation facilities. Everybody has to admit that the American knows how to get there."

"Yes," retorted my friend jokingly, "if everything goes 'O. K.' as you say in America."

SOME PERTINENT FEATURES RELATING TO GAS POWER*

EDWIN D. DREYFUS

DURING the fifteen years of commercial use of the gas engine in this country, abundant experience has been furnished from which may be deduced two features of importance:—

1—The distinct fields of usefulness of gas engines may be determined definitely under any conditions, and, in general, are very well defined. Contrary to the frequent implication that gas is a direct competitor of steam power or other source of energy supply, there are unmistakable regions where a gas plant is unqualifiedly superior; and, on the other hand, there are places where it would be a positive economic disadvantage. Evidently there exists a line of division or equality but occasionally encountered, where the decision rests upon probable changes in industrial or operating conditions.

2—Gas power machinery is less responsive to the ingenious fancy of the designer than the other well-known type of station equipment. Not that it is less reliable, as automobile work evinces, but the prerequisite characteristics of satisfactory operation and continuity of service may be satisfied only by a simple and effective design, from which but small deviation is feasible.

The disregard of these factors more than any other cause has been harmful to the gas engine art in prejudicing against its use, where otherwise is would have proven a judicious selection. Notwithstanding this, the industry has materially prospered, and, owing to its inherent high efficiency in the conversion of latent thermal energy into useful mechanical power, it will increasingly continue to hold the attention of the engineering profession and commercial world as well.

The obtainable gases for engine operation are given below and their approximate constituents and calorific values are given in Fig. 1.

1—*Natural Gas*—Existing principally in western Pennsylvania, western New York, West Virginia, Ohio, Kentucky, Kansas and Louisiana districts. It is virtually a gas having ideal quality, possessing high heat value, free from suspended impurities and absence

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*Extracts from a paper read before the Pittsburgh Railway Club.

of any great percentage of highly inflammable constituents (hydrogen chiefly).

2—*By-Product Gas*—Obtaining mainly in the metallurgical and mining industries, as blast furnace and coke oven gas, and in oil refineries as distillate. Both so-termed metallurgical gases are, in their crude form, accompanied by objectionable impurities—entrained ore dust in the former, and oily vapors, lampblack and sulphurous compounds in the latter, whuch must be removed to a reasonable degree by cleaning and scrubbing apparatus before delivery to the engine.

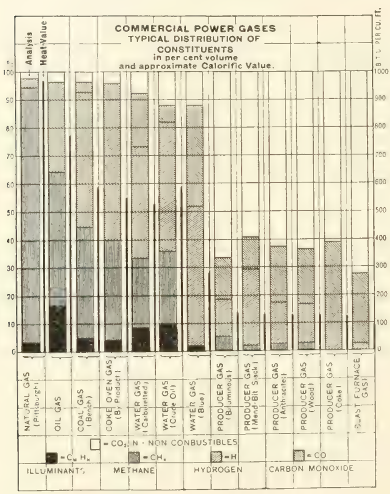


FIG. 1—COMPOSITION AND HEAT VALUES OF COMMERCIAL POWER GASES

3—*Artificial Gas*—As several different fuels and processes are employed in the manufacture of combustible gases, there is consequently a variety of kinds used in gas engines, such as,—

a—Illuminating, or coal gas, produced in benches or retorts by destructive distillation, is available in practically all large cities. It is of high heat value, and, of necessity, a fairly clean gas. There is a high percentage of hydrogen present which compels the use of comparatively low compression to prevent pre-ignition. Owing to the enrichment essential for illuminating purposes, with the added expense of distribution, the cost of this gas to the consumer ordinarily confines its use for power purposes to very special cases.

b—City gas, either made from the partial oxidation of coal and carburetted, or from crude oil, possesses the same limitations as far as the gas engine is concerned. Blue water of somewhat lower

heat value and cost, is also less satisfactory and economical than the familiar producer gas power.

Producer Gas—a—The producer gas from both anthracite and bituminous grades of coal presents the logical solution for the use of the gas engine in the absence of by-product or natural gas at consistently low prices.

b—Oil gas producers for power purposes, have not yet attained a sufficient degree of development to warrant extended use. But where crude oil is the predominating fuel supply, some installations have been made with fair success.

Oil and Gasoline—Only with the unrefined mineral oils is the internal combustion engine able to show true economy. Due to operating and constructive difficulties in the larger sizes, the best possibility of the oil engine has not yet been realized in actual practice in this country.

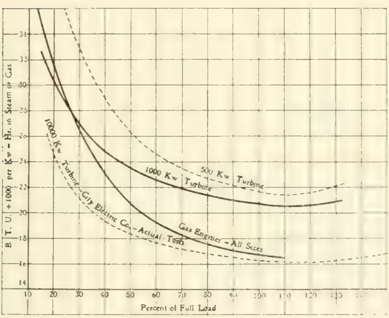


FIG. 2—RATES OF HEAT CONSUMPTION PER KILOWATT OUTPUT

Steam turbine—175 lbs. pressure, 100 degrees superheat, 28 in. vacuum. Gas engine—total heat values.

EFFICIENCIES

The foremost characteristic of the gas engine lies in its uniformly high thermal efficiency over all ranges of size. Such small variations as may be found are trifling. This virtue does not apply to steam units, either reciprocating engines or turbines, and hence, the greatest utility of the gas engine, barring by-product or natural gas supply, will occur in the smaller operations.

As an illustration, Fig. 2 shows conservative heat consumptions in B.t.u. per kw-hr. output for turbines ranging from 500 to 10 000 kw, inclusive, and a typical gas engine curve, which represents all sizes. The latter is expressed on the basis of total heat supply, assuming a gas quality containing a high hydrogen content (lowering the effective value, say, eight percent), preferably to place the two types of units on the same plane. Thus it is evident that as the larger capacities are approached, the disparity between gas and steam units steadily vanishes, either plant at best con-

suming approximately two pounds of coal per kw-hr. Conversely, with a decrease in size of the plant, there is a wider gap between the two types of equipment. Thus the gas plant will continue to develop a kilowatt-hour on two pounds of coal, while the steam station may use eight to twelve pounds.

ECONOMIC VALUE

The impression that gas power invariably implies a lower cost of generation is being dispelled through the critical analysis of the elements of power cost. Fuel is manifestly only a fraction of the entire expense. Customarily a division is made between (*a*) capital charges, embodying interest, depreciation, taxes and insurance, occasioned by investment, and (*b*) the running cost, which includes, fuel, labor, oil, waste, water, supplies and up-keep. To exhibit the importance of the cost constituents, Fig. 3 is given, which is based on plants consisting of two units and burning $3.00 coal delivered.

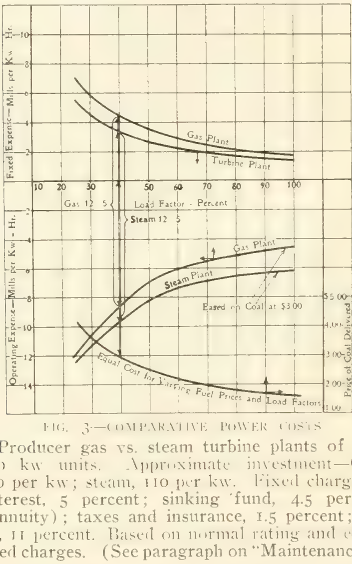


FIG. 3—COMPARATIVE POWER COSTS

Producer gas vs. steam turbine plants of two 300 kw units. Approximate investment—Gas, 140 per kw; steam, 110 per kw. Fixed charges—Interest, 5 percent; sinking fund, 4.5 percent (annuity); taxes and insurance, 1.5 percent; total, 11 percent. Based on normal rating and equal fixed charges. (See paragraph on "Maintenance.")

The composite cost of a gas plant laid down, exceeds that of a high-grade steam station by approximately 30 percent. Such difference is quite normal in view of the character of working in the two plants. The gas engines must be rugged to withstand combustion pressures reaching 450 lbs. per sq. in. Corresponding temperatures may rise to 3 000 deg. F., and, therefore, effective cooling of the exposed surfaces must be provided. In a turbine, the conditions are far more moderate—pressures 150 to 200 lbs. per sq. in. and temperatures in the neighborhood of 500 degrees F. Turbines are operated at such relatively high speeds, that very efficient use is made of the material employed.

Labor in small gas and steam plants will not differ seriously, but the simple turbine, with its minimum of parts, places a severe handicap on the gas engine when high powers are contemplated, contributing another reason for the barrier against the use of large gas engines for central stations burning coal as fuel. Having the size and cost of the plant, together with the schedule of operating labor and supplies arranged, the decision hinges upon the probable load factor and also upon the price of fuel, where it may be subject to variation. It is an obvious fact that low load factors work against the use of expensive installations, notwithstanding their superior efficiency.

Fortunately for the gas plant, the embarrassment of low load factor conditions may be partially overcome by the use of a simple low pressure turbine in conjunction with a heat storage system supplied by the waste heat of the engine and operated to sustain the peak of the load.

Power generation has mainly been reckoned with as applying to central distribution. But in the machine shop, factory and related industries, the power house is surrounded by another demand: viz., heat supply, especially above latitude 37 degrees. The heating requirement has very often been improperly allowed to discount the intrinsic value of the gas plant for the reason that the waste heat energy is not concentrated in the same convenient vehicle for transmission to the point of consumption, as is the case with the non-condensing engine or turbine.

More recently gas engine exhaust heaters have been devised, which render available in the form of steam 70 percent of the heat of the exhaust. While this quantity represents only two pounds of steam per brake horse-power developed, it will evidently prove sufficient where the ratio of power to steam demand is low. Where the *"power steam factor,"* i. e., the ratio of the pounds of steam required to the brake horse-power demand is known, an adequate choice of prime mover may be made, as is illustrated by Table I.

TABLE I.

POUNDS OF STEAM PER BRAKE HORSE-POWER.

Simple Automatic Engine	40
Small Steam Turbine	30
Single Cylinder Corliss Engine	28
Corliss Non-condensing Compound Engine	22
Automatic Bleeder Turbine	20
Complete Expansion Turbine (Bleeding 25% from Receiver)	6
Gas Engine (Waste heat—jacket and exhaust—used in hot water system)	5
Gas Engine only, exhaust applied to steaming	2

Since the maximum heating demanded in industrial work occurs during only the minor part of the year, supplementary heating apparatus may well be provided to ensure the highest degree of economy the remainder of the time.

Natural gas, though an excellent fuel for the gas engine, may only be regarded as available where the cost does not exceed an equivalent power value generated in a producer for a fixed coal price (delivered).

[The author also presented curves giving evaluation of natural gas on the basis of producer gas manufactured from coal at various prices.]

TYPES

More is undoubtedly known of the principles and cycles of operation employed in the gas engine than of the working problems involved. Quite distinct from the steam engine or turbine, the power charge enters the cylinder as latent energy void of any static or dynamic force. It must be compressed a number of atmospheres before it can be burned efficiently. Then combustion takes place, producing a power stroke, followed by a stroke discharging the spent gases from the cylinder. One complete revolution is thus devoted to the preparation of the power stroke, and consequently, an impulse is only exerted upon the crank every second revolution in a single-acting cylinder, and one in each revolution for a double-acting cylinder. This constitutes the four cycle system. Two cycle engines are also in commercial use, and they purpose to do away with the idle stroke, which is achieved by an auxiliary pump, serving a dual function of scavenging the cylinder of foul gases at the end of expansion and delivering a compressed charge of mixture preceding the successive stroke. In this arrangement, two power strokes per revolution are attained. However, the practical application is attended with operating difficulties: viz., loss of unburned fuel in scavenging, low mechanical efficiency (introduced by auxiliary pumps) and frequent renewals and replacement of parts. The four cycle engine is, therefore, today the universal type of gas motor.

Vertical and Horizontal Frames—In smaller sizes the problem resolves itself, in a sense, into a matter of individual preference, But this is not strictly true. Small units are preferably made single-acting to avoid the wear and deterioration of the piston rod and gland packing, subject to the action of the gases. Minimum

wear on cylinder and simplicity of cylinder and piston are evident in the vertical type, such as shown in Fig. 4.

In the larger sizes, the vertical cylinder would become cumbersome and less accessible, leading to expansion and vibrating troubles. The horizontal type has become common practice in large powers, with "floating" water-cooled pistons suspended on the main, intermediate and rear cross-heads (See Fig. 5). Excepting some types of small engines, all horizontals have tandem cylinders, providing two impulses every revolution.

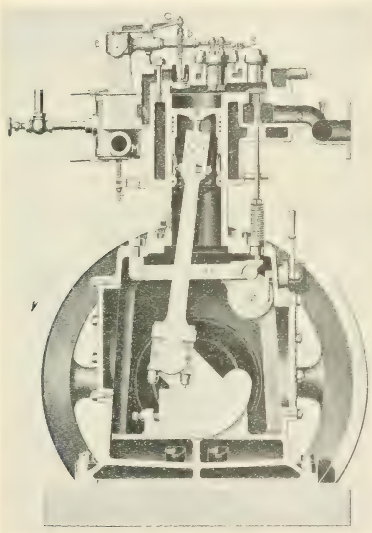


FIG. 4—SECTIONAL VIEW OF A TYPICAL VERTICAL ENGINE

Structural Details.—The fact has already been noted that high pressures and temperatures are encountered in the gas engine. A construction is demanded that introduces no abnormal casting temperatures or working strains, particularly in the cylinders, heads and pistons. Outside of the cylinders and valve gear, the various parts resemble steam engine practice, but are far heavier, due to the greater magnitude of the impulses.

NOTE.—The author devoted considerable attention to details of construction and gave extracts from an article by Herr R. Drawe in the *Iron and Steel Journal* (Berlin, Germany) for February, 1910, bringing out the disadvantages of both the one-piece and the four-pice cylinder constructions, and preseenting certain designs of pistons which have failed in practice. Owing to space limitations, this part of the paper has been omitted.

REGULATION

Of the three methods, "hit-and-miss," "constant quality and variable quantity" and "variable quality and constant compression,"

which have been used commercially, the second principle only has satisfied the vigorous demands of heavy service. A large number of engines have been equipped with quality governing, but this arrangement is giving place to the more stable and simple quantity regulation. Again, to ensure the requisite degree of cyclical regularity, the mixture must be controlled directly adjacent to or above the combustion chamber, as shown in Fig. 5, to avoid any storing of mixture between the governor admission and the main inlet valve.

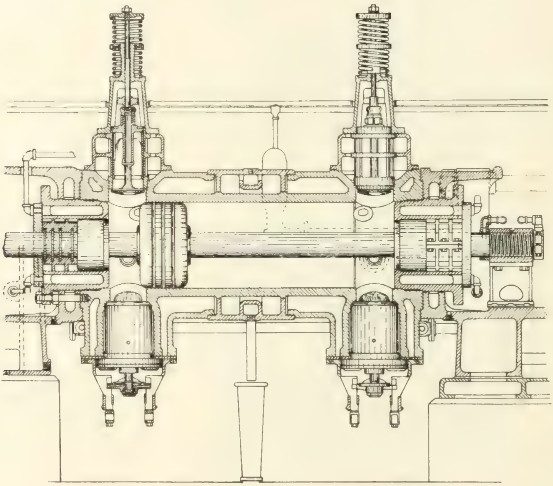


FIG. 5—SECTIONAL VIEW, MODERN HORIZONTAL GAS ENGINE CYLINDER AND VALVE MECHANISM

The reasons are obvious, that the lag before the governor could respond to the load would not be tolerated in important service, and, moreover, back-firing troubles may be seriously augmented.

The modern valve gear, Fig. 5, under test on 60-cycle work, solid coupled engines, operating in parallel at the Union Switch & Signal Company,* maintained a mean angular deviation, with full-load thrown on and off, of 1.95 electrical degrees. Fig. 6

*See description of this installation in THE JOURNAL for February, 1909.

shows the characteristic load supplied by a 750 brake horse-power gas engine at the Perth Amboy plant of the Standard Underground Cable Company, exhibiting the sensitiveness of the governing system to the sudden and repeated changes in demand, and simultaneously providing good voltage regulation.

THE PRODUCER

In view of the limited space admissible, this important phase of the gas power may only be broadly summarized. The foremost considerations resolve themselves into:—1—Suction and pressure types. 2—Dry or water-sealed bottom. 3—In gasifying bituminous fuels, the methods of fixation into a permanent gas or effective removal of the heavy hydrocarbons and oily compounds.

When the operation of the pressure producer plant, with its

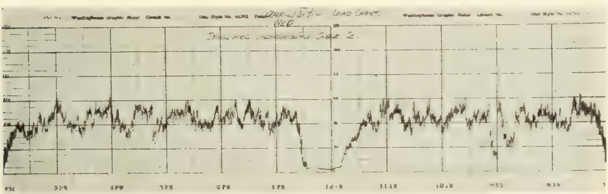


FIG. 6—CHARACTERISTIC LOAD ON 750 BRAKE HORSE-POWER GAS ENGINE
Standard Underground Cable Co., Perth Amboy plant.

disagreeable surrounding atmosphere, is understood, the extended use of the suction type is explained. Moreover, better control and more even oxidation is secured throughout the fuel bed. Continuity of operation is best obtained in the use of water-sealed ash pits, where ash and clinker may be withdrawn from the producer with least interference with the fire or reaction zones. For the average power plant, gasifying a highly volatile bituminous coal, a design is demanded which will, without intermittent operation of the making of burdensome tarry by-products, deliver a good quality of clean gas to the engines.

MAINTENANCE

Present statistics, which may be taken as reliable in the data available, fairly indicate that the maintenance and repair expenses

of well-designed gas power plants of moderate size should be about on a parity with those of high-grade steam turbine stations. That this assertion is reasonable is evident from the fact that the greater cost of cleaning and readjustment of boiler and condenser

FIG. 7—COKE OVEN GAS POWER PLANT
Cornwall Ore Banks Company, Lebanon, Pa. Three 750 kw units.

tubes above the negligible up-keep of the producer, largely counteracts the increased cost of "conditioning" the gas engine above that of the turbine. Hence fixed charges were arbitrarily assumed equal in Fig. 3.

The real difference in obsolescence or supercession in the art in either type of plant is more or less intangible at present, and consequently in order to avoid complication, no distinction has been made.

Table II is given as an example of the operating efficiency of a 550 brake horse-power producer gas plant, including all items of expense.

TABLE II.

DATA ON 550 BRAKE HP GAS PLANT. MONTHLY RECORD OF OPERATING COSTS, DECEMBER 1909. UNIT LOAD FACTOR 80.3 PER CENT; INVESTMENT LOADING FACTOR, 67 PER CENT.

Items	Cents per kw-hr. Producer room	Engine room
Fuel	0.202	
Operating Labor	0.120	0.036
Repairs { Labor	0.008	0.050
Repairs { Material	0.000	0.002
Water	0.030	0.024
Oil and Waste		0.010
Auxiliary Power	0.050	
Fixed expense at 15% on investment	0.127	0.254
	0.537	0.376
Total	0.913	

Here we have a cost of current of less than one cent per kw-hr., which is really a remarkable attainment, considering the size of the plant and the unusual fixed charges imposed (excluding maintenance).

INSTALLATIONS

Gas power in this country today is estimated to represent an aggregate capacity of over 475 484 horse-power, involving the following types in the order of their approximate importance*:—

Blast furnace gas	31	percent
Natural gas	43	"
Producer gas	22	"
Illuminating gas	3	"
Coke oven gas	1	"
Distillate, oil and gasoline†	0.1	"

*Estimated from N. E. L. A. Gas Engine Committee report, 1910. Machines 50 hp. and above only.

†This record only partial.

ASBESTOS

ITS PRODUCTION AND USE

H. R. EDGECOMB

TAKE a certain kind of glass, soften it by heat, draw it out into fine, flexible thread, weave it with care into a fabric incorruptible as to decay and the action of most acids, but not as to heat, and you have approached the limit of man's effort to produce a mineral fibre. Nature makes a shrinkage crack in a mud-like stone, fills it with water, dissolves a little of the mud in the water and crystallizes the whole crack full of threads which are much finer, more flexible, and stronger than the glass fiber, and in addition thereto capable of withstanding a temperature of 2 000 to 3 000 degrees F. Remembering that the water combined in these fibers runs as high as 14 percent of the whole weight, one is forced to the conclusion that some of nature's processes are "past finding out".

The Greeks named this fiber "asbestos" (unquenchable, uncomsumable) ; the Romans made cremation robes of it, and Charlemange astounded his gaping courtiers by casting his well soiled table cloth into the fire and withdrawing it, clean and white for another feast. Nor has it been many years since an otherwise respectable and industrious lumberman was accused of witchcraft and run out of a camp in the Canadian woods because he persisted in washing his socks in the stove instead of by more conventional methods.

ORIGIN

The origin and the conditions contributing to the formation of asbestos are, like most geological happenings, very complex, and while the particular formation to be described illustrates in a general way most of the deposits, it must be remembered that details will vary and also that there are differences of opinion, even among geologists.

Because of its shrinking nature, the crust of Mother Earth has become wrinkled and cracked until the superimposed strata of water-deposited rock are folded and broken, worn and torn, and the rents and wrinkles filled by molten rock from within. In the vicinity of Thetford, Province of Quebec, one of these intrusions of igneous rock occurs. It is, more correctly, a series of rocks, including peridotite, pyroxenite, gabbro, diabase, and others. The peridotite when altered by hydrating is called serpentine. During

the cooling of this peridotite it is supposed that cracks were formed and that the hydrating process which caused the rock to take water into its structure widened these fissures. During the hydrating action the water carrying some of the serpentine in solution collected in these cracks, and eventually the dissolved mineral formed thread-like crystals, usually building up from opposite walls of the crack and meeting or forcing past each other at the center. The cracks are generally straight, but do not occur in parallel planes. they are found crossing each other and running in all directions.

VARIETIES

Broadly, asbestos may be classified as amphibole and chrysotile, the foregoing description applying to the latter variety. The amphibole, or hornblende asbestos, does not have the fineness of

TABLE I—TYPICAL ANALYSES OF ROCK AND FIBER

Chemical Constituents	Serpentine Rock	Italian Chrysotile Fiber	Canadian Chrysotile Fiber	Amphibole Fiber
Silica	40.34	40.30	41.00	61.82
Magnesia	43.32	43.37	42.50	23.98
Alumina	1.32	2.27	0.80	1.12
Ferrous Oxide	1.23	0.87	0.60	6.55
Lime	...	...	...	1.63
Water	14.17	13.72	14.05	5.45

fiber, the tensile strength, the elasticity, or the flexibility of the chrysotile, although it has approximately the same heat-resisting qualities. The amphibole differs from the chrysotile chemically in having lime combined with its magnesia, and while the chrysotile, a silicate of magnesia, is always hydrated, the amphibole is frequently anhydrous.

Referring to Table I, it will be noted that the chemical makeup of chrysotile is practically identical with that of the serpentine rock from which it is formed.

There can be little doubt that there is a definite relation between the softness of the fiber and the quantity of water contained therein; 14.38 percent of water has been found in very silky fiber, while a harsh, brittle sample showed only 11.7 percent. This will explain the extreme brittleness of the amphibole fiber, one sample of which, as indicated in the table, contained 5.45 percent of water. The effect of high temperatures on very soft fiber also demonstrates

this fact. When part of the combined water has been driven off by excessive heat, the fiber loses its flexibility and becomes harsh and brittle, and the variations in strength and silkiness in various deposits of the mineral are best explained by assuming that the water content was originally nearly the same in all cases, and that the movement of associated rocks or the injection of molten rock have furnished sufficient heat to drive off part of the water.

Chrysotile, as indicated above, is best adapted to commercial uses, and, being more important, will form the subject of most of what follows.

PHYSICAL CHARACTERISTICS

Physically, asbestos has some very fascinating characteristics. In the absence of reliable data as to the diameter of its fiber, some

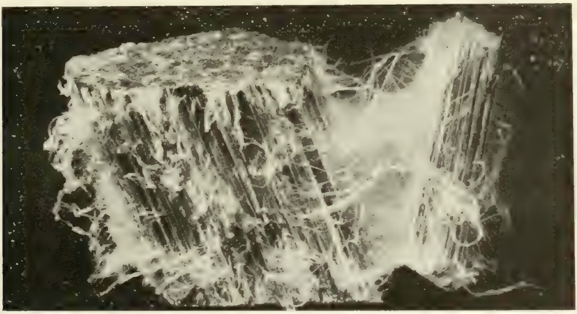
MAIN PIT, BELL ASBESTOS MINES AT THETFORD, P. Q. CANADA
Owned by the Keasbey & Mattison Company, Ambler, Pa.

microscopic observations were attempted. At about 90 diameters the subdivisions of the fibers appeared to be unlimited. The bundles broke up and branched off into numberless finer collections of lines. At 900 diameters magnification, fibers appeared which were barely discernible and which were estimated to be five one-millionths of an inch in diameter. There was, however, nothing to indicate that these were not capable of still further subdivisions, and, as suggested by Mr. A. Kingsbury, who very kindly made this examination, it would not require much elasticity of imagination to believe that the ultimate asbestos fiber is just one molecule in diameter. This seems reasonable, moreover, as, in the case of mica, the cleav-

age is such that specimens have been split to a thickness equal to one-half wave length of distinctly violet light.

Wool, cotton, silk and other fibers all have more or less rough surfaces, and when spun into a thread this roughness aids in holding the mass together. While its fibers are almost infinitely finer than these, asbestos has an absolutely smooth, glossy surface, and for a long time this characteristic prevented the successful spinning of what was otherwise an ideal fiber. The overcoming of this difficulty has made possible the spinning of a fairly strong thread weighing approximately an ounce per hundred yards of length.

The color of asbestos varies greatly and a study of reports from all parts of the world show the following tints:—Pure white, yellow, pale green, grass green, blackish green, blue, gray, brown, salmon, greenish blue, and lavender blue. When fiberized the color



ASBESTOS FROM BELL ASBESTOS MINES

generally disappears, in most cases the flossy crystals appearing entirely white.

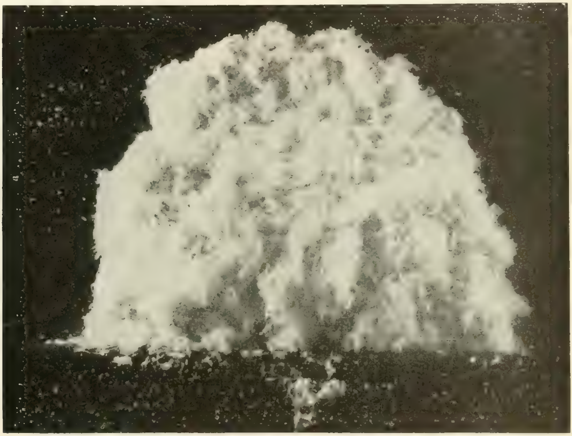
As a material of engineering, asbestos is unique. Soapstone has great heat resisting qualities and is a good electric insulator, but it can only be used where massiveness is permitted. Mica also withstands heat and provides excellent dielectric resistance. Its brittleness bars it from use as an insulator in many cases. Asbestos is to mica and soapstone what the line is to the plane and solid, and later references to its use will bring out this fact more in detail.

GEOGRAPHICAL DISTRIBUTION

At least 75 percent of the world's supply of asbestos is mined in the eastern townships of Quebec. The asbestos-bearing serpentine is scattered through a relatively narrow belt running nearly

northeast from the boundary of Vermont to within about forty miles south of Quebec.

On account of the general distribution of serpentine rock throughout the world, it is not surprising that deposits of asbestos should be discovered in widely distant localities. If the quality were always good, the available useful supply would be much greater than it is. Unfortunately, most of the fiber is harsh and not suitable for spinning and weaving. The United States has many deposits, but they are generally of inferior quality. The largest supply of usable asbestos has come from the Sall Mountain district in White County, Georgia. Dalton, Mass., New Hartford, Conn.,



CARDED ASBESTOS FIBER, NO. 1 QUALITY

Pinto Creek and Grand Canon, Arizona, Bedford County, Virginia, Polk, Mitchell, Wilkes and Yancey Counties, North Carolina, Stevens Point, Wis., Gasper, Wyoming, and Orleans and Lamoille Counties, Vermont, have all produced more or less of the fiber. The deposits in Vermont form a part of the great serpentine region extending across the Province of Quebec.

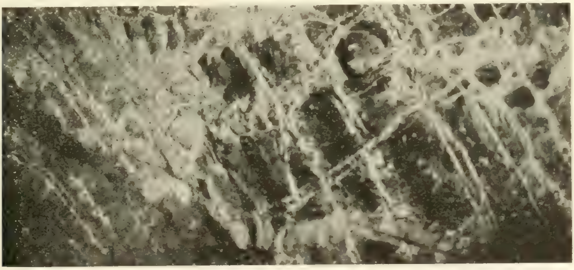
Newfoundland, in the vicinity of Port au Port Bay, has large and promising deposits, but is prevented by its inaccessible location from participating in the rapid development now in progress in the Canadian field.

Italy, up to 1877, produced practically all the asbestos used, and its use was made almost prohibitive by the high prices charged.

These prices were high of necessity, because of the difficulties and hardships of mining, and as soon as the Canadian product was exploited the Italian industry received a decided set-back; nor is it surprising, because Canada has a much greater percentage of good fiber, and Canadian asbestos is more easily spun or woven than is the Italian mineral.

There are extensive deposits in the Ural Mountains of Russia. At Ekaterinburg a true asbestos of fine and silky texture is found, this fiber being valuable for spinning on account of its tensile strength. The work in these mines is done by Russian peasants, who receive for their labor from 33 to 38 cents per day, together with free sleeping quarters.

Mongolia, Siberia, Finland, Queensland, South Australia, New South Wales and New Zealand have deposits which have not as



VIEW SHOWING ASBESTOS IN THE WALLS OF DRIFTS
In the main tunnel of the Bell Asbestos Mines, owned by the Keasbey & Mattison Company, Ambler, Pa.

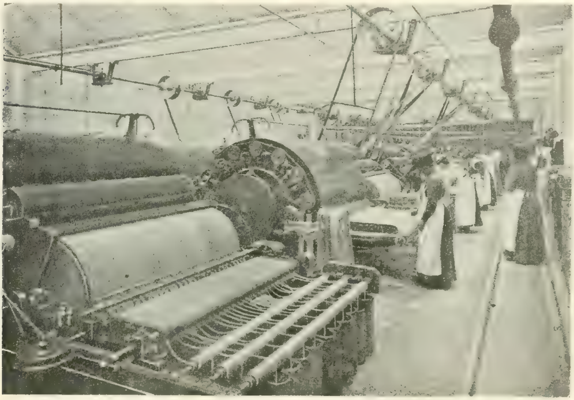
yet been extensively worked. A lavender-blue fiber is mined in South Africa, which differs from other varieties, not only in color but in its specific gravity, which is lower. This fiber has great strength and other good qualities and is becoming a strong competitor of the Canadian product.

PRODUCTION

The production of Russian asbestos has been pushed forward at even a greater rate than the African fiber. In 1902, 45 tons were shipped from the South African mines, and, in 1909, 2 000 tons were exported, at an estimated value of $135 000. In 1907 the Russian mines produced over 10 000 tons, as compared with 1 000 tons in 1900, and they are rapidly increasing their annual output. The startling growth of shipments from these two sources of supply is furnishing food for thought on the part of the Canadian pro-

ducers, whose annual deliveries have only about trebled in eight years.

According to a recent estimate, the world's annual consumption is not over 100 000 tons of all grades of asbestos. Since 1877, when the Canadian industry was founded, the Province of Quebec has supplied at least 75 percent of this, and asbestos mining is without doubt the most important mineral industry in the Province. Up to within a very short time, the mines have been owned and operated by a considerable number of separate concerns. Recently The Amalgamated Asbestos Corporation, Limited, has drawn together a large majority of these concerns, and with a capitaliza-



WEAVING DEPARTMENT
The United Asbestos Company's Works, London, England.

(This and the following illustration are published by courtesy of Eugene Haanel, Supt. Mines, Dept. of Interior, Ottawa, Canada.)

tion of $25 000 000, has launched a trust which controls from 50 to 70 percent of the world's supply of asbestos. In the opinion of H. Mortimer-Lamb,* this merger has grossly over-capitalized a fine industry. The rapid growth in foreign fields is cited as an indication that the Canadian producers may not always enjoy their present monopoly.

The immediate result of the merger has been unprecendented activity, and the opening of new mines and erection of new plants is going rapidly forward. Some of the larger mines are working

*In the *Canadian Mining Journal* of January 15th, 1910.

twenty-four hours per day, using electric searchlights for illumination at night. An Asbestos Bureau has been instituted, its object being to keep the public advised as to new uses to which asbestos may be put, and to report the development of asbestos properties the world over.

MINING

Excepting a few underground workings, asbestos is mined in open pits. When consistent with thorough work, the barren rock is left standing and the fiber-bearing rock removed. In many cases, however, the useless rock is carried off to the dump and the pit left unobstructed. While tunneling work can be continued through-

SPINNING DEPARTMENT.
The United Asbestos Company Works, London, England.

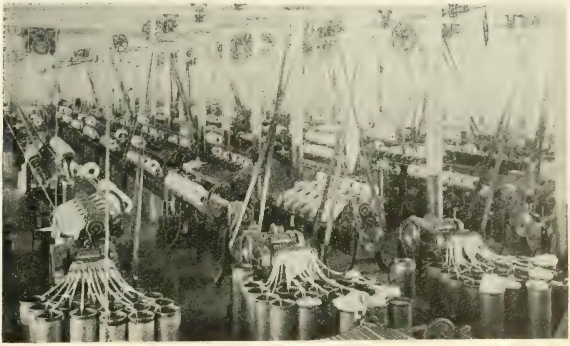
out the year, regardless of weather, it is not well adapted to asbestos mining on account of the irregularities of the deposits and the amount of waste made necessary in order to have suitable pillars and supports. The beginning of an asbestos mine is no small undertaking, it sometimes being necessary to remove a layer of soil fifteen to twenty-five feet deep before actual quarrying can be started. In some of these cases the steam shovel is supplanting pick and shovel, with excellent results as to speed. It may also be suggested that an opportunity is offered for the use of electrically-operated shovels where electric power is available or may be developed. In the quarrying proper the serpentine is attacked with air or steam-driven machine drills, driving holes eight to fifteen

feet deep, and using about one-half pound of dynamite for each foot of depth. Three cents' worth of explosive brings down about one ton of rock. Electric batteries are used for firing the shots. The broken rock is next sorted and lifted from the pit in boxes and placed in cars, the barren rock going to the dump and the fiber and "fines" to the mills for further treatment.

To convey some idea of dimensions, a typical mine might be referred to. This mine is 700 feet long, 200 feet wide, and 165 feet maximum depth. Cable derricks are placed along one side, and the transport boxes of rock are hoisted and carried to the side of the mines by these derricks.

PREPARATION

The dressing of asbestos consists in removing the adhering rock, either by hand cobbing the long fiber, or machine treatment



VIEW OF THE "DRAWING ROOM," SHOWING PROCESS OF DRAWING AND DOUBLING AND COMBING.

In the mill of the Keasbey & Mattison Company, Ambler, Pa.

of the shorter stuff. No. 1 crude asbestos measures over three-quarters of an inch in length, and is worked up by men using six to seven-pound hammers, by which most of the rock is removed. The sorting work is usually done by girls, who break up and sort the fiber.

Putting asbestos fiber into suitable conditions for spinning is by no means an easy problem. To find methods of separating each fiber from its neighbor and from the small pieces of rock has taxed the ingenuity of asbestos engineers for many years. A number of completed plants were failures because complete fiberization was not accomplished. Successful extraction of fiber from the ore dates

back barely fifteen years, and now the great majority of Canadian asbestos is fiberized at the mines.

As a preliminary step the ore is heated sufficiently to drive off all water adhering to the fiber. When dry, the rock passes through crushers which break and grind the bundles of fibers until they are pulled apart. These crushers are, essentially, magnified coffee mills. For still finer separation the fiber passes between rolls giving direct pressure to the bunches of fiber which at this stage are rarely more than three-quarters of an inch in size. After these crushing operations, the fiber is mostly in the form of small lumps, which must be further broken up and put into a flossy, feather-like condition. This is accomplished either by cylindrical beaters or "cyclones". The beaters have rapidly revolving arms with teeth at their ends mounted within a cylinder. The rapidly moving teeth tear the fiber apart and the finished floss is passed out of the cylinder at an opening opposite its entrance point. The cyclones have propeller-like beaters placed opposite each other and revolve at 2 000 to 2 500 r.p.m. The lumps of fibers are fed in so as to strike these beaters, and are hurled against each other with sufficient force to be torn apart and fiberized almost immediately. An exhaust fan draws out the fibers and carries them to a shaking screen, which takes out the remaining lumps. Suction fans carry the finished fiber to collectors and settling chambers. It is sometimes found desirable to pass the crushed ore under magnets to extract small particles of iron.

GENERAL USES

Materials of a fibrous nature enter very largely into the useful arts. This is illustrated by the time-honored use of straw in brick, the mixing of hair with mortar, and the manufacture of paper, rope, braid and cloth. As organic fibers, generally used for these purposes, must be kept at a safe distance from fire, it is natural that intensive engineering should welcome asbestos which assists in space economy and in fuel economy as well. Probably the most striking example of its value is the use of boiler and steam pipe coverings made from asbestos and plaster. A conservative estimate places the fuel saving resulting from this protection at twenty-five percent.

The modern fire fighter can accomplish very much more than was formerly possible, because of his fireproof equipment. His garments, boots, gloves, helmet, mask and respirator (all asbestos),

permit him to remain in direct contact with the flame for a considerable time. Asbestos theater curtains have become a necessity, and asbestos rope makes possible the saving of property and oftentimes life as well.

Rubber sheeting, strengthened by a web of asbestos, makes ideal steam packing, while for the insulation of cold storage chambers and ammonia pipes, asbestos felt, both plain and corrugated, is used. For general heat insulation around stoves and furnaces, asbestos mill board is available. This is made by one manufacturer as follows:—Asbestos fiber is placed in beating engines, with water, where it is thoroughly worked up with a suitable binding cement, and stored in tanks, from which it is fed to the paper machines. These machines have cylinders of fine wire gauze, upon which the pulp is collected, excess water pressing through the gauze. The thin coating of pulp passes from the gauze cylinder on to another drum, and when a sufficient thickness has collected it is cut across and removed. This moist square of millboard is pressed by hydraulic machinery and dried.

Asbestos enters into many materials of architecture. Fireproof brick, wall plaster, floor tiling, shingles, roofing felt, and so-called fireproof paints all have asbestos in their composition, while gas grates are faced with clear asbestos fiber.

ELECTRICAL USES

In the field of electrical insulation, asbestos gives the fireproof fiber necessary to hold together certain other insulation materials. The gums, such as asphalt, rubber, shellac and Bakelite, are moulded with asbestos, and the fiber adds strength to what would otherwise be too brittle for practical use. Asbestos wood or lumber is being used for switch bases and small switchboards. When properly waterproofed by impregnation with asphalt, this material is entirely suitable for these purposes. The unimpregnated lumber has remarkable arc-resisting qualities, and gives excellent satisfaction when used in switch boxes.

In addition to its use in moulded insulating pieces, asbestos is used to insulate copper conductors in coils where the temperatures are relatively high. Field coils for railway and other motors have their life decidedly increased in this way, as a greater temperature rise may be allowed than is permissible when ordinary cotton insulation is used. For this purpose round wire is wound with asbestos thread or tape, and the whole coated with a heat-proof cement, which makes a fairly homogeneous covering. This wire and

flat ribbon similarly insulated are used to some extent for armature windings. Field coils made from edgewise or flat wound copper strap are insulated by winding strips of asbestos paper between turns of the bare conductor.

The Fire Underwriters require the employment of asbestos as a non-inflammable covering for conductor cords used as leads for electric heating apparatus. Copper cable is loosely insulated with asbestos thread and one or more strands thus protected are encased in a cotton sleeve. The destruction of this outer sleeve would not in any way damage the insulating qualities of the asbestos.

OBJECTIONABLE FEATURES

Notwithstanding the uses just indicated, it must be said that asbestos has very serious limitations as an all round insulating material. Asbestos fiber is not as strong mechanically as other fibers ordinarily used for insulating purposes. It cannot be used as an outside covering when it will be subject to abrasion. Mass for mass, the insulating value of asbestos is relatively low compared with the best insulating materials, such as mica or varnish-treated cloths. It is also true that moulded insulating materials containing asbestos do not compare favorably in dielectric strength with those which are made without it. A possible explanation lies in the fact that the relative conductivity of asbestos is greater than that of other fibers. Another explanation is that a compound of two materials having a wider divergence in specific inductive capacity will not be as good an insulator as a compound of two materials having capacities more nearly coincident. Asbestos fiber is more likely to collect moisture than the other fibers, thus reducing the resistance of the mass of which it forms a part. It is probable that all three of these conditions combine in making asbestos a less valuable electrical insulator than many other materials used for such purposes.

Notwithstanding its limitation as an insulating material where high voltages are in question, asbestos will continue to be used to advantage for moderate voltages. In the application of asbestos to electrical work, as well as in its common application as a heat insulator, great progress has been made in the last few years, and without doubt new needs will continue to develop and the demand for this valuable mineral will be greatly increased during the next few years.

WINDING OF DYNAMO-ELECTRIC MACHINERY—VIII

DETERMINING THE FORM OF A DIAMOND COIL

GRAY E. MILLER

THE previous articles in this series have dealt principally with the winding of coils of various shapes and sizes after the coils themselves have been formed or partly formed to their proper shape. In the present article is given a method of determining the proper shape of a common form of armature coil, viz., a diamond-shaped coil. While this description uses as an example a coil for a certain type of machine, the method is general and may be applied to smaller or larger coils of certain characteristics.

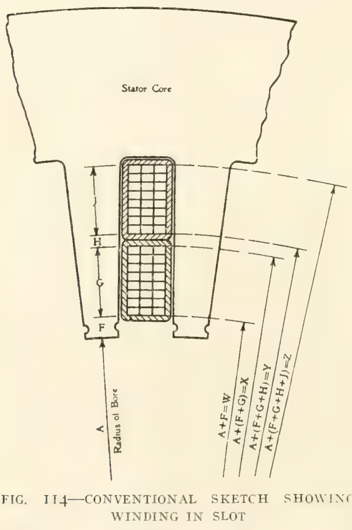


FIG. 114—CONVENTIONAL SKETCH SHOWING WINDING IN SLOT

An exact mathematical derivation of the theoretical form of coil, which would allow all parts to lie snugly together, is not attempted, as such a solution would be complicated and would introduce difficulties in the manufacture of the coil which would outweigh any advantages which might be derived.

To simplify the description, it is assumed that the electrical design of a machine has been completed, and that the diameter of the punchings, the size and number of slots, the size and number of conductors in the slots and the throw of the coil have all been determined. With this as a basis, a method of designing the proper shape of a diamond coil for the stationary part of an induction motor is given.

As a convenient example assume a 750 horse-power, three-phase, eight-pole motor operating at 6 300 volts. At this voltage the insulation space necessary is quite large, and hence the allow-

ances to be made for winding the coils form an important part of the calculation. This will serve to show better the different precautions to be taken for the several portions of the coils. The bore (i. e., the inside diameter of the stator punchings) of the machine chosen is 60.156 in. Half of this is dimension *A*, Fig. 114. There are 180 slots each 0.640 by *2.720* in., and the throw of the coils is *1* and *17*. Each coil is composed of eight turns of three No. 9, square wires in parallel; that is a conventional view of the winding in the slot shows two complete units in each slot, each unit being three wires wide and eight deep.

Since there are 180 slots in the motor and there are two half coils in each slot, it is evident that there are as many coils as slots. We then have to solve the problem of properly disposing of the

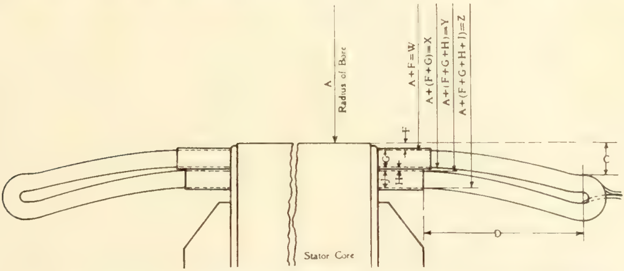


FIG. 115.—SKETCH SHOWING CONVENTIONAL CROSS-SECTION OF WINDING IN A MACHINE

end connections of the coils, i. e., the diamond parts, so that there will be no interference in any way, and so as not to use any more copper than necessary. This is comparatively simple when it is considered that the windings lie in a surface which is so slightly conical that it may be considered a cylindrical surface within any limits of coil extension likely to occur in practice. When the coil extension of a one or two coil per slot diamond winding is so great that too large an error is introduced by assuming the coils to lie on the surface of a cylinder, the actual surface of a cone must be used, and it is then necessary to develop what is called a "cone" winding similar to that used very extensively in turbo-generators.

Reference to Fig. 115, a conventional sketch showing a section of the winding parallel to the shaft, illustrates what is meant by the above. If C is small as compared to D, it is apparent that there will be only a slight error in assuming that the coils lie on

the surface of a cylinder with radius $A + F$ (Figs. 114 and 115) = W. It is apparent also that the bottom part of the top half of the coil will have a different radius X. The same is also true of the top part of the bottom half of the coil and the bottom part of the bottom half of the coil, as shown by radii Y and Z respectively.

It is evident that there is a considerable difference in the diameters of the cylinders on which the top and bottom parts of the windings are supposed to lie. For ordinary use, however, it is sufficiently accurate to assume one cylinder. It has been found best practice to use the cylinder whose radius is W, because, if

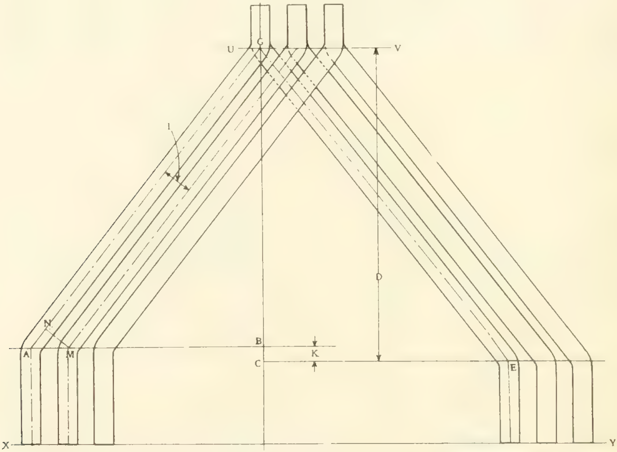


FIG. 116—DEVELOPED VIEW SHOWING ENDS OF THREE COILS

an average cylinder is taken, the part of the coil next the air-gap, which has a radius W, binds so much that it is impossible to wind the coils. It is, therefore, customary to take the cylinder which represents a surface on which the part of the coil nearest the center of the machine rests and design the coil as though all parts of the coil rested on the same cylinder. This results in making the coil just right for any point on the cylinder with radius W and a little larger than necessary for all other parts of the coil. As a rule the extra copper required is not objectionable, or at least not so objectionable as to justify the extra expense involved in making the determinations exactly right for every part of the coil.

Assuming, then, that a coil is to be determined as though it lay around a cylinder of radius W, it is necessary to find the smallest angle for the end connections that will prevent the coils from interfering with one another. Fig. 116, representing a developed view of a few coils, will assist in understanding the principle involved. The line XY represents the end of the iron core developed. The line AB is a line drawn through the corners of the coils and is at a distance from XY equal to the length of the cell extension of the top part of the coil. Similarly the line CE is at a distance from XY equal to the cell extension of the bottom part of the coil. The distance K, representing the difference between these two extensions, is arbitrarily chosen with due regard to voltage and minor points in the design. In this case K is 0.5 in.

Since the radius of the cylinder is W, its circumference is $2\pi W$. There are 180 coils to lay on this circumference and hence each coil can occupy $\frac{2\pi W}{180}$ of the circumference. The problem now resolves itself into determining what angle the coil must have to make its width on a line parallel to XY equal to $\frac{2\pi W}{180}$. It is evident that this width of the coil is the same as the distance between centers minus any air space between the coils. Since this air space is necessary in many cases and in the case under discussion the design of the coil is such as to require an air space, the width of the coil must be considered as the actual width of the copper and insulation plus the air space. With this in mind, L represents the width of a coil and the distance between centers of coils. In the right triangle ANM, shown at the left in Fig. 116, the line MN equals L. It is evident then that the line AM represents the width of the coil parallel to the line XY, when the coil has any given angle NAM with the iron. The distance AM must, therefore, be equal to $\frac{2\pi W}{180}$ as shown above. Knowing the length of the lines AM and MN, the angle NAM is determined. From this angle and the length of the line AB, the distance BG may be calculated, and hence the length of wire necessary to make the coils just wind with any given thickness of insulation and air space is determined. In practice, however, it is easier to make the calculation of the distance BG partly graphic and partly mathematical and to use a projection of the coil rather than a development. The above discussion will serve to fix in mind the principles involved, and the following description will give the actual method used.

Referring to Fig. 117, with O as a center and a radius equal to A (Fig. 114), describe an arc BEC. Concentric with this describe another arc KZ with a radius equal to the radius of bore A (Fig. 114) plus an amount equal to the distance of the wedge groove below the air gap. These circles represent, then, the inside diameter of the punchings and the circle of the bottom of the wedges in the top of the slots. On the arc BEC, Fig. 117, lay out a chord BC, whose length is the distance between the centers of the two slots containing one coil. Since there are 180 slots total and the coil lies in slots *1* and *17*, thus encircling 16 teeth, the angle BOC equals $(\frac{16}{180} \times 360)$. Calling this angle $\propto$, the chord BC equals $2A \sin \frac{\propto}{2}$. Through the points B and C draw the lines OP and OV representing the center lines of the slots in which the coil lies.

On the line OP, lay off the radial distance BM equal to F (Fig. 114), which equals the thickness of the wedge and insulation on the coil. The distance OM, therefore, equals W in Fig. 115. Now lay off a distance MP equal to G (Fig. 114). This distance is the amount of space occupied in depth of slot by one coil and in this case is equal to the thickness of one insulated wire, 0.137 in., multiplied by eight, since the coil is eight turns deep. On the line OV lay off the distance CS equal to $F + G + H$ (Fig. 114), and lay off the distance SV equal to J (Fig. 114). It is evident that $SV = MP = G = J$ (Fig. 114), since they are the top and bottom halves of the same coil. The line OT bisecting the angle $\propto$, represents the point of the diamond on the coils and for coils made on the adjustable pulling machine may be assumed to come in the center, if the coil extension is any considerable amount. Lay off on OT the distance EN, so chosen as to make the angle NMO a right angle if possible. If considerations of design make it essential to decrease EN, the decrease should not be such as to make the line MN intersect the arc KZ, for this would cause interference in the air-gap. Since the line MN is a projection of the coil end, the distance NQ equals MP and similarly RT equals SV. The distance RQ is the diameter of the pin around which the coils are formed, and is chosen with due regard to the thickness of the insulating material on the coil. In this case it is one inch. The point U is the center of this pin. The lines MN, PQ, RS and TV give a projection of the coil on a plane perpendicular to the shaft.

The width of the coil L (Fig. 116) is found by multiplying

the thickness of one insulated wire, 0.137, by three, since the coil is three wires wide. To this must be added the thickness of the insulation and the amount of air space. The total thickness of this coil is, therefore, 0.760 in., using an allowance of three-thirty-seconds of an inch air space for ventilating purposes.

Since the coil is to lie on a cylinder of radius W (Fig. 115), which equals OM, Fig. 117, the angle NAM (Fig. 116) is found by the formula,—

$$\sin NAM = \frac{L \times n}{2\pi \times OM}$$

where L is the distance between centers of coils (Fig. 116), n is the total number of coils and OM is the radius of the cylinder (Fig. 117). The length of the diamond part of the coil BG (Fig. 116) is, therefore MN (Fig. 117) $\times$ $\tan NAM$ (Fig. 116), and the total extension of the coil beyond the straight parts, not including the bend, is $BG + K$ (Fig. 116). This gives the length D in Figs. 115 and 116. The total length of the coil beyond the iron is then found by adding to D, the length of the straight part of the bottom of the coil beyond the iron, the radius of the pin, the depth of coil and the thickness of the insulation. This distance determines the width of brackets necessary to protect the windings.

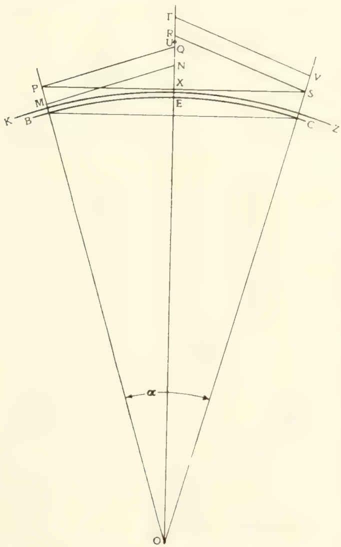


FIG. 117—GRAPHIC PROJECTION OF ONE COIL IN A PLANE PERPENDICULAR TO THE SHAFT

If the coil is to be made on a mould no other calculation is necessary to determine the shape of the mould. If the coil is to be made on an adjustable pulling machine it is necessary to find the distance between the centers of pins on the shuttle in order to wind the proper length of wire. This is readily obtained by drawing the line PS and solving the triangle PQX thus formed, in connection with the triangle ABG in Fig. 116. Then $\propto$ represents the

angle to which the coils should be pulled; *OP* represents the radius of pulling; *PS* serves as an excellent and convenient check on the angle α ; and *OU* represents the distance to which the coils should be "kicked" up. The distance the coils should be extended is given by referring to Figs. 115 and 116 and is equal to the distance of the center of the pin from the iron.

Whenever it is possible, all coils are made on an adjustable coil pulling machine . This method has several advantages. The cost of winding the coils on a shuttle and then pulling them open to the proper shape is very much less than winding the coils to finished shape on a former. The cost of the shuttle on which the coils are wound is very small compared to the cost of a former or mould; and the shuttles are to a certain extent adjustable with very inexpensive changes. Soldered joints inside the coil may be avoided in many cases by the use of the pulling machine. Coils can be formed with certain shapes of conductors which at one time were thought impossible of commercial manufacture. Shorter delivery dates are possible because of the time saved in the development and manufacture of moulds and formers. And finally, the storage space necessary for these moulds and formers is done away with, as a very small supply of adjusable shuttles is all that is required.

In the above description no attempt at refinements has been made, and for the ordinary coil none is necessary. If, however, the coil has a very wide throw, as in the case of two-pole machines, where the angle α may be as much as 180 degrees, complications arise which require the use of every precaution and refinement in the design of a coil, a discussion of which would be beyond the scope of this article.

A CLUB FOR ENGINEERING GRADUATES

J. E. SWEENEY

MODERN industry is recognizing more and more its dependence upon scientific methods and upon scientifically trained men. Graduates of technical schools are welcomed into industrial companies where facilities for their special training and advancement are provided. Probably in no branch of industry has the importance of technically trained men been more appreciated than in the electrical field. In the engineer's preliminary years, experience in factory and testing room are matters of first importance. Supplementing these, other means for advancement are sometimes provided.

The following account of the development of a club, formed primarily for the advantage of the young college men in a large electric works, is not merely typical of the attitude of the modern industrial corporation towards college men, but it shows in a concrete, definite way just how this work is carried on.

The Electric Club with which so many readers of the JOURNAL were familiar was organized March 19th, 1902, with an initial membership of one hundred and fifty, consisting principally of engineering apprentices and the engineers of the Electric Company. The club has grown steadily and has fulfilled its object so admirably that it has naturally paved the way for a broader and greater organization, and on May 9th, 1910, it was reorganized as The Westinghouse Club. The Club now, as the name implies, embraces in its membership men from the various Westinghouse interests in the Pittsburg District, and as a result the activities of the Club have greatly expanded.

For new quarters the Club was fortunate in securing the Royal Building, in Wilkinsburg, a residential suburb of Pittsburg, where commodious club rooms and an excellent gymnasium have been fitted up to meet the requirements, and here may be found one of the most unique clubs in this country.

With a membership of whom the majority are university graduates from all parts of the world and to which each year is added about three hundred new graduates, it is easy to see how the activities of such a club are maintained. The personnel of the Club is continually changing as the members leave to take up duties elsewhere. More than twelve hundred engineering apprentices have been members of the Club since its organization, and a great number of these are now scattered here and there all over the world in responsible positions. It would be difficult to imagine a better opportunity than is afforded by such a club for one to become acquainted with other young men whom he should know in his fu-

ture engineering career, as well as older and experienced men in his field of work.

The Club provides for educational, social and athletic activity among its members. It is governed by a board of thirteen directors, chosen, for the most part, from the younger men, who are thus responsible for the direction and success of the Club. Incidentally, an important advantage of Club membership to these young men is this experience gained in conducting such an organization.

The various activities are in charge of general committees.

GENERAL VIEW OF ONE OF THE CLUB ROOMS

The following is a list of the present standing committees and their chairmen, the club manager and physical director:—

Athletic Committee	A. G. Ahrens
Entertainment Committee	C. R. Jones
Excursion Committee	G. E. Stoltz
House Committee	G. Blocksidge
Lecture Committee	K. C. Randall
Library Committee	G. H. Lewis
Membership Committee	T. E. Simpers
Music Committee	F. S. Balyeat
Publication Committee	C. F. Scott
Publicity Committee	R. A. Duke
Technical Section Committee	C. R. Dooley
Club Manager	S. M. Anson
Physical Director	H. H. Provin

The field of activity as covered by these committees has been laid out on broad lines in order to interest all types of men and to

give each man all that he is willing to do in the line that is most interesting to him. While the name of each committee implies the general character of its activities, a few words regarding the scope of the work will probably be of interest.

The Athletic Committee, in addition to having charge of such sports as baseball, basketball, tennis, etc., has general charge of the gymnasium. The gymnasium has a floor space of 65 by 140 feet and is equipped for basketball, handball, and indoor baseball, as well as volley ball. A physical director has general supervision and conducts regular classes in which systematic exercises are given. Special classes are also formed in boxing, fencing, wrestling, etc.

VIEW IN CLUB ROOMS LOOKING DOWN CORRIDOR FROM RECEPTION ROOM

The Entertainment Committee arranges for dances, smokers and various other forms of amusement.

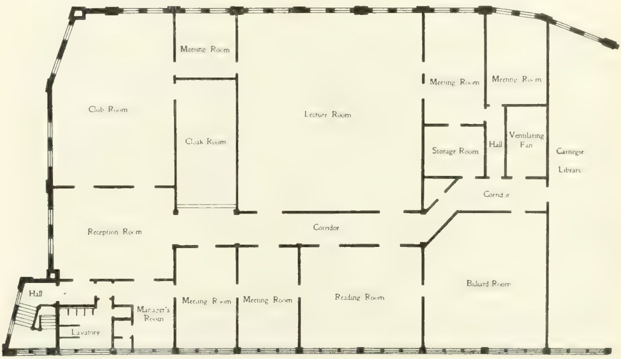
The Excursion Committee arranges for the systematic inspection of notable industrial features and other points of interest in and around the famous Pittsburg District. This affords an apportunity of observing first-hand and thereby gaining a comprehensive knowledge of rolling mills, tube mills, blast furnaces, coal mines, cement mills, glass works, locomotive works, oil wells, machine shops and other plants which are of interest to engineers.

The duty of the Publicity Committee is to see that due notice is given regarding all Club activities.

The duties of the House and Membership Committees are the same as usually pertain to such committees.

The Lecture Committee arranges for weekly lectures, which cover a wide range of subjects, dealing particularly with general engineering, social, economic and national problems. The speakers are the foremost specialists in their line, including men of national importance.

The Library Committee has general supervision of the Club library. In addition to the collection of technical books, a complete



FLOOR PLAN OF CLUB ROOMS, SECOND FLOOR

file of current magazines on engineering subjects, as well as popular magazines and newspapers, is kept.

The Music Committee fosters glee and mandolin clubs and an orchestra and the Club makes use of the talent of these organizations at various entertainments.

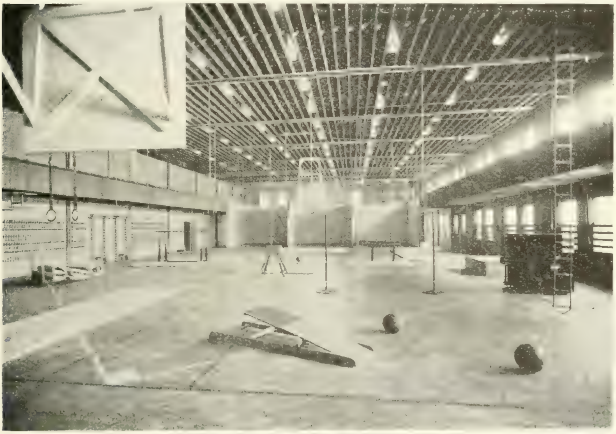
The Publication Committee has general supervision of the technical publications of the Club, which includes THE ELECTRIC JOURNAL.

The Technical Section Committee has in hand the predominating feature of the Club, the educational work. These sections are technical or engineering classes organized to deal with the construction and application of various types of apparatus, or to consider other matters of importance in industrial organization and management. They supplement the daily work of the engineering ap-

prentice in the factory. During the term ending December 21st, 1910, the work was divided into the following sections, each section having its own leader:—

APPARATUS SECTIONS

Brake Equipment Section	B. F. Key
Detail and Switchboard Section	F. W. Harris
Gas Equipment Section	L. A. Quayle
Illumination Section	C. E. Clewell
Industrial Motor Applications Section	C. W. Drake
Industrial Motors and Controllers Section	C. G. Tarkington
Power House Equipment Section	J. Bache-Wiig



VIEW OF CLUB GYMNASIUM

Railway Equipment Section	L. G. Riley
Railway Project Section	E. W. P. Smith
Signaling Equipment Section	E. R. Coe
Steam Equipment Section	H. F. Schmidt
Transformer Section	E. C. Stone

GENERAL SECTIONS

Accounting Section	W. J. Patterson
Materials and Factory Testing Section	L. W. Chubb
Road Experience Section	J. L. Yardley
Sales Section	F. S. Balyeat
Works Management Section	A. S. Duncan

J. H. Mustard, Section Director

The apparatus sections are limited to about thirty men, but the general sections are unlimited as to number. Each section has

ONE OF THE CLUB TENNIS COURTS

a leader who is especially qualified to handle his particular subject. A definite plan of work is outlined for each section and meetings are held every two weeks.

THE CLUB BASE BALL FIELD

Beside the direct personal gain that the various Club activities offer to the men as individuals, it develops between the members as a whole the spirit and temperament which are so essential to the success of men who are to work with others in any great undertaking.

EXPERIENCE ON THE ROAD

TESTING ELECTRIC RAILWAY TRACK-CIRCUITS

LEONARD WORK

ELECTRIC railway track-circuits when out of repair may often be the cause not only of a considerable loss of power but of very poor line regulation. When the resistance of a track circuit becomes abnormally high, one of the first things to be investigated is the condition of the rail bonds. As it is obviously a considerable task to test each individual joint in a long track circuit, a much easier procedure, in many cases, is first to measure the total resistance at once and, by comparing the result thus obtained with that which should be obtained when the track is in good condition, determine the advisability of testing each bond separately.

During a recent investigation of a small interurban electric railway system, following its purchase by another company, one of the items that came up for consideration was that of the condition of lines and track. It was not thought expedient to test each rail-joint on the line unless indications should warrant, so it was decided to first make a general measurement of the actual resistance of the overhead network and track circuit between various points on the road and the power station which would serve to determine whether or not these circuits were in first class condition. The proposition would seem, at first thought, to be one involving considerable time and difficulty; such, however, was not the case, and as actually carried out proved to be a very easy and efficient scheme.

The first step was to obtain the lengths of feeders and trolley line. For this purpose a car was sent over the road at about schedule speed in order to make a count of the trolley suspension poles and to determine the location of each feeder tap. From this data, a map of the line was sketched and as the distance between the poles was uniform, the lengths of feeders, trolley wires and track were easily calculated. From the sizes of wire and weight of rail, assuming the bonding in good condition, their respective normal resistances from both ends of the road and five intermediate points to the power-house, were calculated.

The next step was to measure accurately the resistance of the lines and track circuit combined, from the different points to the

switchboard at the power-house, by firmly connecting trolley to rail at the different localities and observing the voltage required to send a fairly heavy current over the circuit (a direct application of the ordinary ammeter-voltmeter method of measuring resistance). This was accomplished in the following manner:—

After the road had ceased operation for the night a special car was sent out provided with a ground plate attached to some 30 feet of cable, and operated by two men whose orders read as follows:—

> "On arrival at destination run wheel of car on ground plate. Keep lights and heaters turned on. Signal power house to take off power by opening overhead switch three times. When power goes off, note exact time and at once wrap end of ground cable around trolley wire. After ten minutes from the time noted remove ground connection from trolley wire. When lights again come on steady proceed at once to next station and repeat as above."

The progress of this car as it left the barn for the end of the line, the first point of test, was followed by watching the switchboard ammeter. The time of arrival, the process of running on to the ground plate and the faint signal from the overhead switch were as apparent as though the observer were on the spot. On receipt of the signal the engine was at once slowed down until the line pressure was about 25 volts. The line switch was then opened and the exact time noted. After waiting three minutes power was again put on at this low voltage, whereupon the ammeter plainly showed that the men outside had made their ground connection secure. The speed of the engine was now increased and the voltage carefully raised until between 75 and 100 amperes were flowing. Several volt-ammeter readings were rapidly taken, after which the voltage was again lowered and the power taken off. After 12 minutes from the previous time noted the line switch was once more thrown in. The ammeter now showed that the ground connection had been removed. The line pressure was at once brought up to normal, 550 volts. Very soon, by noting the meter indications, it could be seen that the car had started for the next point of test, where the same cycle of operations was gone through, and so on until the last station had been tested.

Thus with no other means of communication than the switchboard ammeter, the entire series of tests was made with a clock-like

precision and a perfect understanding at all times between the men on the car and those in the power house. The testing of approximately seven miles of road at seven different localities required only two hours. The results showed a resistance of from 30 to 90 percent above normal and indicated the necessity for a test of all the track joints. This subsequently was done, as is customary, with a special bond-testing milli-voltmeter, by noting the drop around each rail joint. For this purpose a current of some 20 amperes was maintained in the rails from the lights and heaters of a car which was stationed at one end of the line during the time the bonds were being tested. More than 200 track joints with high resistance were located, and it was agreed that in this case some new electric railway bonds would be a good investment.

In calculating the values of resistance from the power-house to the respective points of the line which served as test stations, the fact that the 2/0 trolley was, in some cases, paralleled by 3/0 feeders had to be taken into consideration. The resistance values

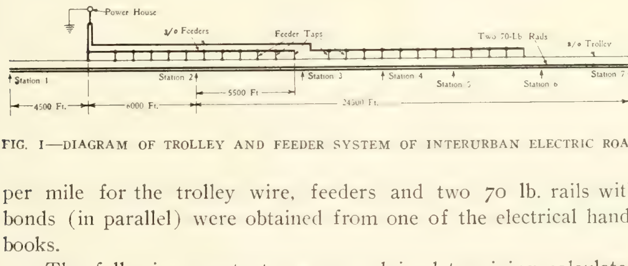


FIG. 1—DIAGRAM OF TROLLEY AND FEEDER SYSTEM OF INTERURBAN ELECTRIC ROAD

per mile for the trolley wire, feeders and two 70 lb. rails with bonds (in parallel) were obtained from one of the electrical handbooks.

The following constants were used in determining calculated values:—

> 2-70 lb. rails bonded; res. per mile = 0.038 ohm = 0.0072 ohm per 1 000 ft.
> 2/0 trolley wire; res. per 1 000 ft. = 0.078 ohm.
> 3/0 feeder; res. per 1 000 ft. = 0.0618 ohm.

The arrangement of trolley and feeder circuits, feeder taps, and location of test stations are shown, approximately to scale, in the diagram Fig. 1, the various distances between stations required in making the calculations being indicated.

As the power-house was located adjacent to the road, the distance from power-house to track did not have to be considered, in calculating the feeder resistances.

Table I gives some of the results obtained for the calculated and measured values of resistance from the power-house to the points of test.

TABLE I.

		Station No. 1	Station No. 2	Station No. 7
Approx. distance to power house		4 500 ft.	6 000 ft.	30 500 ft.
Calculated Resistances	Line	0.351	0.176	1.344
	Track	0.0324	0.043	0.211
	Total	0.3834	0.219	1.555
Measured Resistance	Volts / Amps	57 / 105 = 0.543	42 / 117 = 0.359	79 / 42 = 1.88
Percent high		42	64	21

As an illustration of the method of figuring the respective resistance values to the various stations, the calculations for station 2 are given as follows. The values of the calculated resistances of

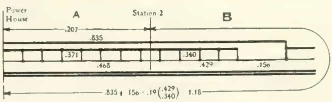


FIG 2—DIAGRAM SHOWING CALCULATIONS FOR FEEDER AND TROLLEY CIRCUITS BETWEEN POWER HOUSE AND STATION 2

the respective branches of the circuit involved between this station and the power-house are indicated in Fig. 2.

First half of overhead circuit (A):
- 2/0 trolley 6 000 ft. @ 0.078 .... = 0.468
- 3/0 feeder 6 000 ft. @ 0.0618.............. = 0.371
- Joint res. in parallel..................... = 0.207 ohm

Second half of overhead circuit (B):
- 2/0 trolley 5 500 ft. @ 0.078 .... = 0.429
- 3/0 feeder 5 500 ft. @ 0.0618.............. = 0.340
- Joint res. in parallel.................... = 0.19 ohm
- 2/0 trolley 2 000 ft. @ 0.078 .... = 0.156
- 3/0 feeder 135 000 ft. @ 0.0618......... = 0.835
- Total res. overhead circuits............. = 1.18 ohm

A, 0.207 ohm, in parallel with B, 1.18 ohm, $= \frac{1.18 \times 0.207}{1.387}$ ..... = 0.176

6 000 ft. track to Sta. 2 @ 0.0072...................... = 0.0432

Total res. to Sta. 2.................................. = 0.219 ohm

THE JOURNAL QUESTION BOX

Our readers are invited to [illegible] for simple [illegible] on electrical and mechanical subjects. The [illegible] should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

520—Principle of Operation of Alternating-Current Fan Motor—Please explain operation of Westinghouse alternating-current fan motor. How can the direction of rotation be reversed? [illegible]

Twelve inch and sixteen inch type of fan motors for alternating current are of the single-phase [illegible] induction type. The [illegible] winding is provided with an auxiliary starting winding which is cut out by a centrifugal switch during acceleration. This is explained in article on "Armature Windings" in the Journal for August, [illegible]. The motor is provided with a choke coil connected in series with one side of the main circuit with switch for cutting it in and out, for purpose of speed control. The motor is reversed by connecting the starting leads in reverse order to the main leads. The starting winding terminals are always brought out between the main leads. The eight inch type of motor for alternating-current is of the series commutation type. Reversal of direction of operation is obtained by reversing either field or armature connections within the motor, depending on convenience.

521—Principle of Operation of Wagner Single-Phase Self-Starting Motor—In the Wagner single-phase self-starting motor, how does shifting the pointer of the brush rocker change the direction of rotation? P. T.

The Wagner self-starting single-phase motor is of the repulsion type. The brushes are not connected to the external circuit but are simply connected together by the rocker arm. The commutator is thus short-circuited at as many points as there are brushes. By induction due to the alternating-current in the stator, there will be a potential difference between [illegible] the commutator. In Fig. 521 (a), which illustrates a two-pole machine, the potential will be a maximum between the points *a* and *b*, and zero between the points *c* and *d*. This assumes that the end connections are such that the line joining the brushes is the magnetic axis of the armature. If the brushes are placed [illegible] current [illegible]. The current

[illegible]

[illegible] the winding between the points *c-a* and *b-d* will produce a torque in one direction and in the winding between *a-d* [illegible] torque in the opposite direction. As the [illegible] equal the resultant torque on the armature will be zero. If the brushes are shifted from the position *a-b* to *c-f* the opposing torque will no longer balance and a resultant torque will therefore appear. By shifting the brushes to the opposite side of *a-b* it will be seen that the resultant torque will be of opposite sign and the motor will rotate in the opposite direction. If the brushes are shifted to the point *c-d* the torque will again become zero, as in this plane the potential is zero and no current would flow. F. C.

522—Soldering Bars and End Rings of Squirrel Cage Motor— Trouble has been experienced in making the bars in the rotor of a squirrel cage motor stay fast. The solder seems to break loose between the bars and short-circuiting ring. Ordinary solder, half tin and half lead have been used. H. M'C.

If the trouble is due to careless or defective workmanship in originally soldering the bars to the rings, careful soldering may possibly relieve the trouble. Solder is used primarily for reducing the electrical resistance of the joint and not for mechanical strength. If the rupture is due to mechanical stresses it can be overcome by the addition of proper bolts or screws. The breaking loose of the bars from the ring may be caused by heavy secondary currents at starting, which melt the solder, thus allowing the bars to fly out due to centrifugal force before the solder can set. The addition of bolts or screws might relieve this trouble, or, if the starting conditions are unusually severe, a change in resistance rings might be necessary unless relief from the heavy starting conditions is possible. M. B. W.

523—Changing Capacity of Meter Current Transformers—We have 300/5 power-factor meters and ammeters. Since the load of the system has not reached 300 amperes as a maximum, and in fact only reaches 100 amperes, could not 100/5 current transformers be used in order to get a full scale deflection? In other words, with increased station capacity could not currents be changed and not both currents and meters? C. P. B.

It is practicable to use 100/5 ampere series transformers with meters intended for use with 300/5 ampere transformers if the load is continuously small enough to warrant. With the new connections, indications on the power-factor meters will be correct, but the ammeter readings must be divided by 3 to give the correct readings with the transformer of one-third primary capacity. H. W. B.

524—Aluminum Electrolytic Rectifier for 28 Amperes Capacity— A set of tests is to be made with an electrolytic type of cell, with aluminum and lead electrodes, and boric acid as an electrolyte, for rectifying alternating-current. The cells are to be of the regular storage cell size. What area of plate will be required to give 28 amperes without overheating, and how many cells will be required? The voltage is 110 volts. J. S.

The making of an electrolytic rectifier to deliver 28 amperes for an appreciable time is an expensive and difficult undertaking. To deliver three amperes for an hour or more, an area of 20 sq. in. for the aluminum plate and an area of 75 to 100 sq. in. for the lead or iron plate would be sufficient, providing three of four sq. ft. of radiating surface were provided to dissipate the heat. For 28 amperes these quantities would have to be multiplied by nine. Such a rectifier is rather inefficient, 30 percent being good, and as the efficiency decreases with rise of temperature the apparatus is very unstable and tends to overheat and begin to boil if slightly overloaded. About six such cells would be required for the delivery of 110 volt direct current. A transformer having a middle tap and about 125 volts from this tap to each outside terminal would also be required. Practically all such rectifiers are limited to two or three amperes capacity and only intermittent service. A motor-generator or mercury rectifier would probably be found to do the work more efficiently and much more satisfactory. R. P. S.

CORRECTIONS

In the article by Mr. Clewell, in the December issue, page 957, the 16th line should read "2.5 watts per square foot" instead of "25 watts per square foot" as published.

In the article by Mr. Copley, in the December issue, page 986, the 13th line should read "10 000 volt range" instead of "100 000 volt range" as published.

THE

ELECTRIC JOURNAL

Vol. VIII FEBRUARY, 1911 No. 2

The Application of Electric Motors

The growth of electric drive in industrial establishments has been gradual until within the last few years, during which time it has made rapid strides, due to the careful analytical study of the benefits to be derived from electrically driven machinery of various kinds. The reasons for applying motors to these several industries resolve themselves into two main factors: either increasing the quantity of the material produced, or bettering the quality of the material, or a combination of both, resulting in either case in a reduction in the cost of the article.

In glancing over the several articles in this issue of the JOURNAL referring to electric drive as applied to certain industries one is impressed by the special character of each installation. Each industry has its own conditions to be met and each type of machine to be driven has its own particular requirements. These must be understood and the electric power adapted to them in order to secure the best results.

Hence, in order to properly apply the motors to produce these results, it is essential that a careful study be made of each industry and of each type of machine used in any particular industry with a view to determining the proper characteristics which should be embodied in a motor to operate the various machines to best advantage.

In order to apply the proper motor a special type of engineering is essential, which may be termed application engineering, and the recent rapid advance in the application of electric drive is largely due to careful study of minute details of various manufacturing processes by a new class of engineers, namely, application engineers, who not only have to be electrical and mechanical engineers, but also what might be termed "process engineers." These engineers have done a great deal to advance the industrial and commercial position of this country, for the cost of production of many lines of articles has been reduced through their careful, analytical studies. They have been able to reduce the costs to the consumer in many instances and yet increase the profits to the manufacturer.

There are comparatively few skilled men of this type, and extended experience is rare because this field of work is so new. In one sense this kind of engineering calls not merely for the individual engineer but for a comprehensive organization. The field of application is so wide, the data necessary is so varied and must be secured from so many places under so many different conditions, that comprehensive application engineering is beyond the capacity of the single engineer. A man can be a specialist in only a few lines. The engineer of a central station company may be called upon to advise as to the application of motors in a dozen or a score of different classes of service. His advice is wanted as to the proper method of applying the power, as to the size and kind of motors most suitable for the specific conditions, and as to the cost of operation which, in turn, is dependent upon load factor and other conditions. Data on similar applications elsewhere, beyond his own personal experience, would be useful to him. Hence comprehensive and efficient application engineering makes essential a fund of accessible data drawn from experience and service records derived from many sources. This is obviously beyond the range of the individual engineer or operating company, but is a matter which has been taken up by some of the larger manufacturing companies in order that they may adapt their product to the service requirements and that they may lend valuable assistance in the installation of motors.

Articles describing the application of motors to a given industry are particularly serviceable if they give not merely the facts but an explanation of the conditions and the engineering reasons why certain methods have been adopted. An intelligent account of the application of motors in one industry may be suggestive and helpful in cases which may at first seem quite diverse. For example, success in many industries besides the manufacture of steel is coming to depend more and more upon the economies and refinements with which they are conducted. Hence, a discussion of the methods by which these advantages are secured in the electric driving of the rolls in the steel mills is of much wider interest than the single industry, as similar methods may likewise be applied to other industries where similar problems arise. The intermittent application of power, the use of fly-wheels, the proper adjustment of speed to the work to be done, the means of producing power from gas or from steam which may now be going to waste—all these are matters in

which the experience gained in the steel industry may afford a useful example to be followed elsewhere.

The better adaptation of motors to the work to be done, the specific requirements of speed variation and the like, essential to the efficient operation of certain machines, has, in a large measure, been made possible by the development of suitable control apparatus. Improvements in control appliances and the production of motors specifically designed both in their electrical and mechanical characteristics to meet the varying needs in diversified industries are resulting in much better apparatus for supplying power than existed a few years ago. The designing engineer and manufacturer are doing their part to promote the efficiency of electric drive, and it now rests largely with the application engineer to make that specific and effective application of motors which will promote the more efficient and cheaper operation of our varied industries by a continued extension of the use of electric power. S. L. Nicholson

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Central Station Power

Central Station people have taken a much more active interest in the commercial branch of their business in the past two or three years. Many of the smaller companies which have been furnishing city lighting and a small load of commercial and residence lights have come to realize that their earning capacity is limited compared with their investment and the cost of operation. As a solution they have established day circuits, and at a slightly increased operating cost have secured a greatly increased income. This has generally been accomplished by new business getting methods.

One small company in particular, just out of the hands of receivers, accumulated several thousand dollars the first year under the same management, as a result of power business obtained. A number of moderate sized plants in towns of from 10 000 to 25 000 inhabitants formerly went on the apparent assumption that if they made too much show they would be suspected of too great prosperity and some hardship might be inflicted upon them. They required customers to visit a dingy office in an out-of-the-way place, either at the plant or on an upper floor of some building. They have now discovered their mistake and in a number of cases have not only re-equipped or rebuilt their plants with modern apparatus of higher efficiency and reliability, but have also established large, cen-

trally located and attractively equipped offices and display rooms where those coming to the office as well as those passing by will see numerous electrical devices and have an opportunity to secure literature upon subjects in which they are interested. Light and power solicitors and demonstrators have also been added, which a few years ago would not have been even considered.

Companies which, in a half-hearted way, were formerly willing to accept what they term "off-peak" business at a reduced rate, are now becoming more liberal and realize the value of energetically developing the power business. Industrial plants, too, are becoming interested and are beginning to make investigations on their own account, largely due to increasing intelligence and interest in power cost. It is not an uncommon thing for power users to approach electric companies for information and many purchased power installations have resulted from such investigations, some amounting to several thousand horse-power. Each increase makes more easy the future extension of power business.

It is difficult to supply the rapidly increasing demand for experienced commercial men. Assistance is being afforded in this field by the interchange of central station data through the National Electric Light Association and by the efforts of certain manufacturers who are taking an active interest in the subject. The results secured by both these agencies are greatly increasing the commercial efficiency of all who are interested in this most fascinating and instructive work.

At recent national and state electric light conventions the commercial part of the program has been increased in proportions that almost threaten to interfere with what was formerly considered necessary routine business. Not over five years ago commercial subjects received scarcely more than passing consideration at these conventions.

At the present rate of development a few years will show wonderful results in the electrical business and practically all central stations will be conducting their business in the same manner as an active, up-to-date, successful merchant or department store manager, who believes that the way to dispose of his merchandise is to let the people know what he has to offer by using methods of publicity which create interest and an intelligent understanding of the benefits which the customer may secure.

W. B. Wilkinson

Corona and the Ionic Theory

Prof. Ryan's treatment of the phenomena of corona as set forth in his recent paper before the American Institute of Electrical Engineers is essentially that of the physicist rather than that of the engineer. The end and aim of the physicist is to find the *cause* of the phenomenon he studies, to find the law that correlates that phenomenon with others of a like character. His eternal question is why? why? why? In this respect Ryan's treatment differs materially from that of Mershon who presented a classic paper on the same subject in 1908. Mershon's viewpoint as indicated in this paper was essentially that of the engineer rather than the physicist. His object was to discover and disclose not so much the *cause* of corona as is Ryan's, but the limitations that corona places upon transmission voltages. Ryan studies corona with a view of tracing it back to its cause, Mershon with a view of tracing it forward to its result. The physicist's interest is scientific, the engineer's utilitarian. The physicist's eternal question is, *Why?* the engineer's, *Of what use?*

It is fortunate that the American Institute of Electrical Engineers occasionally receives a paper like that of Prof. Ryan. It is well engineers should be occasionally reminded that it is the physicist that after all must give the true foundation for all engineering; for the engineer in his application of nature's forces to the benefit of mankind must follow the paths which the physicists hew out.

Ryan's paper bears the cumbrous and somewhat misleading title of "Open Atmosphere and Dry Transformer Oil as High Voltage Insulators." He shows in his discussion that the ionic theory can be invoked to explain practically all the phenomena of corona that have been observed. Briefly the ionic theory assumes that each ultimate particle of matter is dual in its nature, being made up of one part carrying a negative charge of electricity and another part carrying an equal and opposite positive charge. These two parts of the ultimate atom are called *ions*. Normally, these two parts are bound together and make up a neutral particle or atom so that the ultimate particle under normal conditions is carrying no charge of electricity either positive or negative. The two oppositely charged particles which form this ultimate atom are held together by an exceedingly strong mutual attraction. However, due to constant emanations from the earth (caused perhaps by radium or some other radio-active substance contained therein) there are a certain number of free ions constantly floating around in the atmosphere. In the neighborhood

of a charged electric conductor these ions are attracted and repelled due to a well known law of electrostatic forces, viz., that like charges repel and unlike charges attract each other. At all voltages, therefore, there is a certain loss from a charged electric conductor due to the attraction and repulsion of these free ions. Moreover, when a conductor has reached a certain voltage (called the critical voltage) the ions that are repelled and attracted attain so high a velocity that they begin to ionize particles heretofore neutral by collision. That is, the velocity of the ions expelled from and attracted to the charged conductor becomes so high that they knock apart and break down the bonds that unite the positive and negative ions of some of the surrounding neutral atoms thereby forming new free ions. The energy necessary to repel and attract these new free ions must also come from the charged conductor so that at the critical voltage and above, the power required for this purpose begins to increase very rapidly.

So far as the engineer's or utilitarian standpoint is concerned, Ryan's treatment adds practically nothing to what Mershon already discussed and disclosed in his paper of 1908. However, Mershon's results were entirely of an empirical nature while Ryan's are based upon a fundamental law. Ryan tells us no more about the limits to which high-tension voltage can be carried than Mershon had already done. However, it is a satisfaction to know that Mershon's results, as well as those of all others who have studied this phenomenon of corona, can be correlated under a general law and a satisfactory reason assigned such as Prof. Ryan has so ably shown in his latest paper.

P. M. Lincoln

The Problem of the Engineering Graduate

One of the difficulties encountered by an engineering graduate in making a decision as to his future work is that the conditions are not very definitely understood. The case may be likened to the effort of a high school graduate were he to try to decide what elective work he should choose all through his coming college course. He does not know the meaning of the different subjects. It is the experience of many young men who have chosen a graduate apprenticeship course in a manufacturing company to find after a year or so that their ideas undergo a very considerable change. They discover new fields of interest and of value of which they had had scarcely a conception. They assign new values to knowledge and to experience. Matters which had seemed

of small moment they find are being given first consideration by men of mature experience. One young man told me recently that he thought two years ago an apprenticeship course was the thing to take if he could not get anything else, and so he took it. But now he considers it fortunate that no more alluring prospect greeted him upon graduation. The difficulty was that he did not understand concretely what such a course really meant and was unable to put a proper value on a post-graduate course in practical service, where he could at the same time work, learn and progress.

Some graduates take a post-graduate course to get an advanced degree; others accept fellowships and devote themselves to research. The courses offered by large manufacturing companies are somewhat similar in being post-graduate courses, but they are courses in practical affairs in which the man does not aim to acquire more theory, but comes in contact with a great variety of commercial apparatus which he studies from the standpoint of design, of construction, of performance and of application. His theoretical training is not made a basis for higher abstract theory, but for understanding the operation of commercial apparatus and for studying at first hand the products of the foremost engineering minds. This useful technical knowledge, combining both the theoretical and practical, becomes a substantial basis for his future work in whatever department of his profession he may enter. Furthermore, among the actual surroundings of manufacturing and commercial life, he is learning to do by actually doing. This course bridges over the chasm between school life and practical life often pointed out by men of mature experience, but rarely comprehended by the student.

Each of the large electric manufacturing companies, with its course including hundreds of graduate students, is affording a training in electrical engineering which in amount and importance is contributing more than any engineering school in the country toward the development of electrical engineers. Some of the advantages of this training I indicated in an article in the JOURNAL of April, 1910. The importance of such courses is becoming better understood both by the companies themselves and by the professors of electrical engineering and the graduate students. To some, such a course with its somewhat strenuous requirements and its lesser pay than can at times be secured elsewhere, is looked upon as a hardship to be avoided, but on the other hand the better students are coming to look upon it as an opportunity which they cannot afford to miss.

The necessity for reproducing in the training course itself the typical conditions of the professional and commercial life for which it is a preparation is well illustrated by an analogous condition in connection with the public schools quoted from Prof. John Dewey's Moral Principles of Education to which reference is made in the excellent paper on "The Continuation Schools of Munich" presented in the auditorium of the Engineering Societies Building in New York on December 8, 1910, by Dr. George Kerschensteiner:—

"I am told that there is a swimming school in a certain city where youths are taught to swim without going into the water, being repeatedly drilled in the various movements which are necessary for swimming. When one of the young men so trained was asked what he did when he got into the water, he laconically replied, 'Sunk.' The story happens to be true; were it not, it would seem to be a fable made expressly for the purpose of typifying the ethical relationship of school to society. The school cannot be a preparation for social life, excepting as it reproduces, within itself, typical conditions of social life."

Chas. F. Scott

Resuscitation From Shock

Intelligent first aid to the injured in emergency cases such as serious electric shock or drowning may, in the majority of cases, be the means of saving life otherwise unnecessarily sacrificed. The spirit of the article on "Artificial Respiration," by Dr. Chas. A. Lauffer, in the present issue of the Journal, is to offer accurate and concise information regarding the effective handling of such emergency cases. The essentials and the supplementary details are so presented that they may be readily understood and remembered, but too much stress cannot be placed upon the necessity of preparing for emergencies by thoroughly familiarizing oneself with at least the essentials through *practice*, as suggested by Dr. Lauffer. The directions given in the present article are based on a careful study of available literature on this subject supplemented by a wide experience in the actual treatment of such cases.

IRRIGATION BY ELECTRIC POWER

ALLEN E. RANSOM

THE watering of arid lands by means other than those of nature, to increase their powers of producing grains, fruits and vegetables, is an old subject, but the various means of irrigation which have been developed by human ingenuity afford an interesting study. For centuries past many fertile spots along the Nile have been watered by simple buckets pivoted on long sweeping arms, which dip into the river's current and swing up to the extent of their arms, where the water is emptied into a small pocket-like reservoir. From this reservoir in turn another similar bucket and arm lift it up again, and so on for five or six sweeps, until from the upper level, sometimes thirty to sixty feet above the stream, the water can trickle down through the sandy soil.

A brief summary might be made of the various schemes used to water the soil and increase its productive qualities, where nature has failed to provide moisture in sufficient quantities, as follows:

1—The bucket and sweep in successive units operated by man power.

2—Natural gravity using canals, and distributing by means of branching laterals.

3—Natural gravity with the water under pressure through banded wood stave pipes, with either open laterals or small machine banded wood pipes for laterals with the smaller sublaterals of galvanized iron pipe, all under pressure.

4—Pumping by means of centrifugal or piston pumps, using either steam or gas engines, water wheels or electric motors as sources of energy. The source of water supply may be either surface water from the streams, or may be ground water, secured by sinking wells.

Irrigation by gravity systems can, of course, be accomplished only in those favored localities which have a natural source of water supply at a level higher than the tract under cultivation. Such locations have long ago been appropriated, so that further extensions are dependent upon some source of power for pumping. Long distance transmission lines, carrying power from the mountain streams and water falls over the intervening dry plains to the growing cities and towns of Colorado, California, Nevada, Oregon, Washington and Idaho, have made pos-

sible the use of electric motors for the operation of pumps for irrigating purposes. In fact, the ease and economy with which electricity can be transmitted over wide areas and used to drive motors, makes electric pumping in many cases preferable to the gravity system. The pumps can be in comparatively small units, each supplying a local area. The distributing ditches are small, thus leaving maximum area for crops, and the water supply to each area is always under perfect control. There is minimum danger of broken ditches and flooded crops, such as sometimes occur with large ditches.

The sage brush and sand covered plains of these states, when properly cultivated and flooded with water, produce the

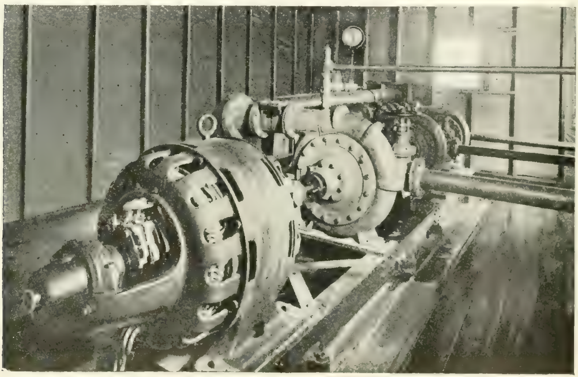


FIG. I—PUMPING STATION OF THE EDEN ORCHARD TRACTS, WENATCHEE, WASHINGTON

wonderful grapes, melons, peaches, cherries, apples, strawberries, etc., which are now a common sight in the markets of this country. Land, which less than a decade ago could be purchased for from fifty cents to two dollars an acre in the valley of the Columbia, is now holding its own at $150.00 an acre for alfalfa hay land, producing three crops a year and averaging four to nine tons an acre at $10.00 per ton. This condition of affairs has brought these lands before investors, large and small, from all parts of the country, and where ten years ago individuals held vast areas of this cheap land, the rising values have now reversed those conditions. Increasing numbers of settlers hold smaller tracts, and dividing and sub-dividing is constantly

going on. Intensive cultivation is the secret of successful irrigation to the man of moderate desires, and with the same amount of care and attention bestowed upon the land, ten to twenty acres or even less of good irrigated land will produce more than much larger areas in the East, particularly when devoted to the raising of fruits.

The results obtained by this intensive method of cultivation of small unit areas of land have been the greatest factor in opening up the various tracts of irrigable lands in the Pacific Coast States. Organized companies have taken up tracts of land in units of from 160 to 6 000 acres and have divided them into small tracts of 5, 10, 20 and 40 acres each and sold them to homeseekers, with water rights, at prices ranging from $100 to

FIG. 2—DISTRIBUTION SYSTEM OF THE EDEN ORCHARD TRACTS, WENATCHEE, WASHINGTON

$600 per acre, the land being in its original prairie form but with the water delivered thereto.

A concrete example of an operating company in the upper Columbia River Valley may be of interest. This company has taken a 160 acre unit of sage brush land, platted it into five and ten acre tracts and supplied it with water under a pressure system. The pumping station, Fig. 1, consists of a 40 hp, three-phase, 60 cycle, 2 300 volt, wound secondary induction motor, direct connected to two 3.5 inch and one five inch centrifugal pumps. These pumps are so arranged that they may be run in single, multiple or series stages to supply water for the different heads to be pumped against. They have the following duty:

250 gallons per minute to a head of 190 feet, all three pumps in series;
500 gallons per minute to a head of 160 feet, two small pumps in parallel pumping into the large unit;
750 gallons per minute to a head of 110 feet, the arrangement being the same as with the 160 feet head but the pumps operating on reduced head and picking up more water;
500 gallons per minute to a head of 55 feet, the five inch pump working alone as a single step pump.

The main discharge system from the pumping system is a 12-inch double riveted flanged steel pipe, 1 700 feet long. The lateral system is made up of galvanized sheet steel pipe of various diameters, branching from the main discharge line and having at intervals one inch stand pipes about two feet long, with valves which feed the water into the small distributing

FIG. 3—BOOTH OF THE PACIFIC POWER AND LIGHT CO. AT THE WASHINGTON STATE FAIR, NORTH YAKIMA, WASHINGTON

ditches, as shown in Fig. 2. The loss of water by evaporation is thus minimized and by means of the stand pipe system the irrigator is enabled to control the flow as he works on the distributing ditches.

This system proves more economical to the holder of the small five and ten acre tract than would obtain if he had to purchase an individual pumping equipment for his land, as the Power and Land Company carry the necessary investment for electric sub-station, pumping station and water distributing system, and although he pays more per acre for his land under these conditions, the terms of sale are such as to make it less of a financial burden, than would the individual unit pumping plant.

In this particular case, assuming a load-factor of 80 percent on the pumping plant on 24-hour service, the average station load would be about 32 horse-power. It would thus be easy to keep the mechanical equipment in good running condition, even though the full load of 40 horse-power might be carried at times for short intervals. Basing the power bill at $7.00 per month per horse-power on the peak or maximum demand, the charge would be $280.00 per month as a possible maximum or $1.75 per acre per month for the 160 acres affected. The water could thus be delivered at a maximum cost of $17.50 per month for a ten acre tract from a central pumping plant, where an individual plant of, say, a three horse-power unit would require a

FIG. 4—POMEROY GULCH IMPOUNDING RESERVOIR OF THE LEWISTOWN, CLARKSTON IMPROVEMENT CO., LOOKING TOWARD CLARKSTON, WASHINGTON

monthly charge at a higher rate per horse-power, besides the maintenance, attention and cash investment.

These figures, of course, are roughly comparative as the cost of power differs materially in different localities, but they indicate in a general way the advantage secured by the small owner, in getting his water from a central unit station rather than putting in the small individual unit. The tendency is increasing, therefore, towards the installation of larger sized pumping units to supply sub-divided tracts of land, both on account of the economy in step-down transforming stations in larger sized units, and for the reason that where power is purchased the large sizes of pumping equipments offer more op-

portunities to make the installation along good engineering lines, and to build the station and equip it with machinery of high class manufacture, reliability and efficiency. The small unit station of three to ten horse-power, on the other hand, tends to the purchase of any pumping outfit that will turn over and the equipment of lowest first cost many times turns out to be the most expensive in the end. It is not infrequent for these small units to have a combined plant efficiency of from 25 to 40 percent.

The hydro-electric transmission companies are naturally assisting in this movement, as the irrigation projects through the

FIG. 5—ASOTIN CREEK POWER STATION OF THE LEWISTOWN, CLARKSTON IMPROVEMENT CO.

Water received from Asotin Creek through a 7-mile, 48-inch wood stave pipe line. Penstock, 40-inch steel pipe. Head, 475 feet. Capacity 3 000 hp.

country traversed by these trunk lines form a natural and very desirable market for power. Their exhibits and booths at the various state and county fairs, such as that shown in Fig. 3, are now a common sight, and are the center of much interest. Many of the larger projects have substantial impounding reservoirs which, as in the case shown in Fig. 4, catch the tail water from their hydro-electric stations at a higher elevation than the irrigated valley, and from which the water is distributed under pressure to the towns, orchards and fields below. This reservoir is a part of the system of the Lewiston, Clarkston Improvement Company, at Clarkston, Washington, which dis-

tributes water for irrigation purposes under gravity pressure to a considerable area surrounding these cities. At the same time, by carrying the first part of their 48-inch wood stave pipe line around the hills at a considerable altitude, a head of 475 feet is made available for their 3 000 horse-power hydro-electric generating station, Fig. 5, located on Asotin Creek, six miles above the town. Power is thus made available for lights and industrial uses and also for pumping water for irrigation purposes where it is difficult to supply gravity pressure. The water in the main flume is at a sufficient pressure when it reaches the town of Clarkston to furnish a head of 250 feet to a 400 kw generating station located just above the town. The tail water from this station is impounded in the reservoir shown in Fig. 4, for gravity irrigation of the lower levels, water being taken from the main flume for the higher levels. In all, this company has seven miles of 48-inch, four miles of 40-inch, two miles of 36-inch and one mile of 30-inch wood stave pipe line.

The two hydro-electric power stations operating in conjunction with a 500 kw steam turbine auxiliary station furnish power to the towns of Lewiston, Clarkston, Asotin, Genessee and Moscow, through a total of over 50 miles of transmission line at 45 000 volts.

An alfalfa ranch of about thirty acres in the Eden Orchard Tracts was sage brush land four years ago at $20 per acre. When the water was put on the land two years later, it immediately became worth $100.00 per acre. With improvements on the tract costing approximately $1 500.00, the owner was recently offered $260.00 an acre for the whole tract. Twenty acres in the first crop of alfalfa of the year produced fifty tons of hay which sold sixty days after stacking at $9.00 per ton in the stack. A ten acre, four-year-old fruit ranch in the Yakima Valley was purchased two years ago complete with land, water rights, and buildings for $2 800.00. This summer the owner refused $5 000.00 for the place.

Irrigation has produced these changes and, by a succession of events, electricity has become the principal factor in developing and making accessible these vast arid tracts, which are becoming rapidly transformed into gardens, orchards, towns and cities, with inter-connecting interurban systems, electric lights and telephones.

PAPER MACHINES WITH MOTOR DRIVE

C. W. DRAKE

IN THE electrical equipment of pulp and paper mills it has been found that with very few exceptions the squirrel-cage induction motor best meets the requirements of the service. The exceptions are those applications which require an especially high starting torque over an extended period, for which purpose the slip ring induction motor is used, and also paper machines which require adjustment of speed over a wide range in order to obtain various weights of paper. The direct-current motor still holds the field for adjustable speed work, so that although an alternating-current system should be used for the plant as a whole, it is necessary to have direct current for the operation of the paper machine itself.

Paper machinery may be grouped into two general classes, namely, Fourdrinier and cylinder machines, the principal differences between them being at the wet end of the machine. The paper on Fourdrinier machines is formed on a continuous wire screen known as a Fourdrinier wire, while with cylinder machines the paper is formed on wire cylinders. The former machine is used principally for the lighter weights of paper and those made from a single grade of stock, while the cylinder machine is used principally for cardboard and felt work which may use several kinds of stock at one time. The former is essentially a high speed machine, while the latter runs at a slower speed, although from a motor point of view this makes little difference since the speed reductions are obtained by gears in the machine drive.

The drive for any paper machine consists of two main parts, namely, a constant speed section and an adjustable or variable speed part, as it is usually termed. The constant speed portion consists of the various stock, water and vacuum pumps at the wet end of the machine, together with the screens and other auxiliary apparatus which are installed there. The variable speed portion consists of all sections of the machine upon which the paper is formed and finished. Constant speed induction motors are well adapted for the constant speed section of the machine, and it is only for the variable speed shaft that adjustable speed motors are required.

The speed range required by any machine depends primarily upon the various weights of paper it is expected to make upon it.

If each machine could be run with one weight of paper at all times, speed adjustment would be almost unnecessary. This is the case with several plants which manufacture newspaper only and are using slip ring induction motors for the variable speed shaft. This type of drive allows of 10 to 25 percent decrease in speed, but a large speed range will not be satisfactory due to the poor regulation of the motor when operating with resistance in the secondary. Large mills, which operate several machines, can so distribute their orders as to keep each machine working within narrow

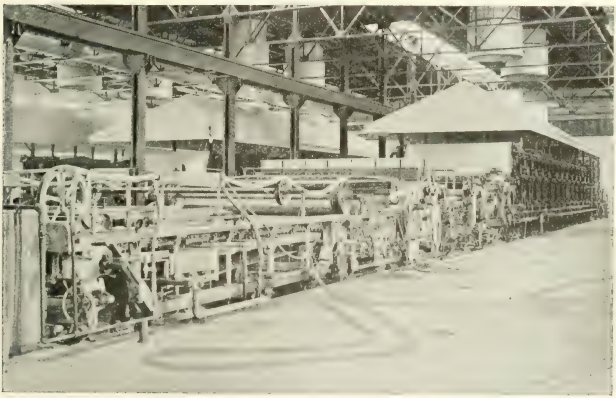


FIG. 1—OPERATING SIDE OF 150-INCH FOURDRINIER MACHINE

The wet end of the machine is clearly shown with the Fourdrinier wire and the deckle, which limits the widths of the sheet on the wire. Just beyond the deckle strap is seen the dandy roll which gives the water mark or other impression desired. Below the wire, just beyond the dandy roll and in front of the couch roll which drives the wire, are located the vacuum boxes, where a vacuum of 10 to 12 inches tends to draw superfluous water through the wire. Each pair of the press rolls which the paper enters after leaving the wire also removes some of the moisture, but the paper nevertheless enters the dryers containing about 65 percent of water.

speed limits, thus operating at better efficiency and requiring less expensive driving mechanism. A small plant, on the other hand, unless producing a special product, may require a speed range as high as 7:1. Higher ratios are sometimes requested, but it is seldom required to make paper over the whole range, and the higher the ratio, the greater the investment for electrical equipment. Eliminating those machines which may be driven by alternating-current motors, the various methods by which the variable speed shaft of a paper machine

may be driven by direct-current motors will be considered, together with the limitations and advantages of each.

MECHANICAL LAYOUT

Practically all mills of recent design make use of a basement in which the line shaft for the paper machine is rigidly and permanently installed on concrete piers. For the maximum speed of the paper machine this shaft usually runs at from 250 to 350 r.p.m., so that for machines requiring motors of 75 hp or over, it is not impracticable to couple the motors to the shaft. A much cheaper and entirely satisfactory drive is obtained by belting the motor to the

FIG. 2—DRY END OF 142-INCH AND 152-INCH BOOK-PAPER MACHINE

The paper passes from the dryers to the calenders where the pressure from the heavy polished steel cylinders produces a smooth finish. All or part of these calender rolls may be used, depending on the finish desired. From the reel at the end of the machine, the paper is slit and rewound in widths as desired.

shaft so that a maximum motor speed of 800-1 000 r.p.m. may be used. When there is not sufficient space between centers for a good belt drive, it is more satisfactory to use a chain drive.

The greater part of the power taken by a paper machine is required to overcome the friction of the various sections of the machine. In fact, that part of the load caused by the paper is practically nothing more than an added friction, so that the total load may be considered as one made up of friction. This being the case, it is to be expected that for various speeds the same torque would be required; or, in other words, the horse-power would be proportional to the speed. Numerous tests have shown that the above

statement is approximately correct, although over wide ranges of speed the ratio between horse-power and speed is found to be not quite identical. This deviation from the rule is probably due in part to the different action of heavy paper from light paper in the machine and also to the different action of lubricants at various speeds.

It has often been assumed that the load of a paper machine when running at a given speed and manufacturing a certain weight of paper will be constant, but this is far from true. On a Four-

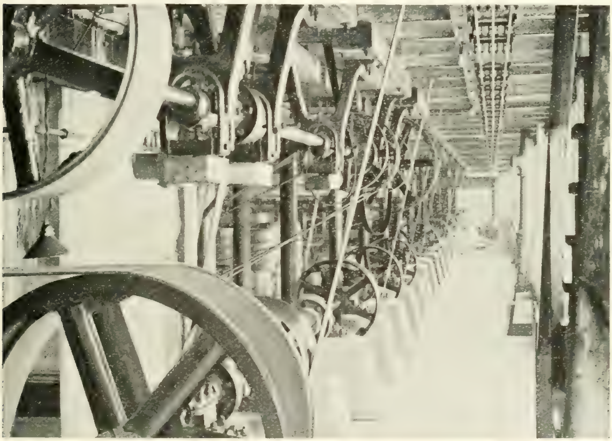


FIG. 3—LINE SHAFTS FOR A PAPER MACHINE

The constant speed shaft, suspended from the ceiling, drives the pumps, screens, etc., at the wet end of the machine. The variable speed shaft supported on the floor, drives all the sections upon which the paper is formed and finished. The long shaft is necessary in order that all sections of the machine may be driven at exactly the same speed, to avoid tearing the paper. The pulley driving the machine is slightly tapered, and speed adjustments between the sections are made by changing the location of the belt on the pulley. The concrete supports insure accurate and permanent alignment of the shafting.

drinier machine, for instance, there are four principal places where the power consumed may be varied while maintaining a constant speed and product. These are—first, at the couch or wire, the load varying here according to the pressure on the roll and also with the vacuum in the suction boxes; second, at the press rolls, the variation here being caused principally by the weights, or pressure on the rolls, although poorly lubricated journals often cause considera-

ble variation in power; third, at the calender, where, for a given sheet, the principal variation is due to the number of nips taken, the throwing on and off of the stack and the condition of the journals; fourth, the winder, which works only intermittently since the paper is slit and rewound at a speed about double the speed of the machine. The throwing on and off of the winder may cause quite an appreciable change in the total load.

A proper understanding of the above conditions is necessary

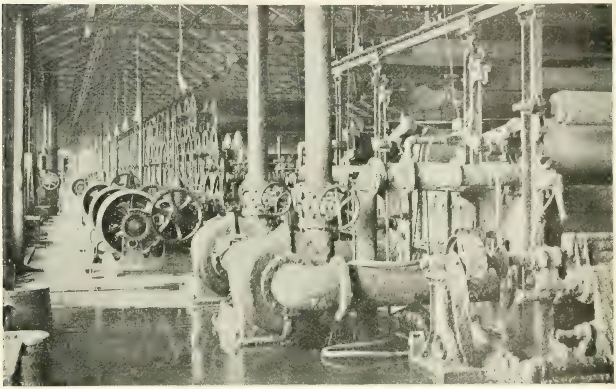


FIG. 4—DRIVE SIDE OF A 120-INCH, TWO CYLINDER PAPER MACHINE

The prepared pulp is maintained at a constant level in the cylinder chests shown at the right. The water passes through the mesh of the wire cylinders, leaving the paper fiber adhering to the outside of the cylinders in uniform layers, the thickness depending on the height of the pulp in the tanks and on the speed of rotation. The cylinders are driven by a wide band of felt passing over them, to the under side of which the pulp adheres and is carried to the dryers. Any number of cylinders may be used, each adding a layer of paper of any composition or color desired. The water is removed from the inside of the cylinders by pumps shown in the foreground, and used in the preparation of other pulp.

Each section of the steam heated dryers, shown in the background, is driven through a double reduction gear by a belt from a shaft in the basement.

to decide upon the allowable speed regulation in the motor. If the load were absolutely constant at any setting, the question of regulation would be of no importance. To understand the effect of poor regulation, it is necessary only to recall that the stock is being pumped to the wire at a constant speed and that any variation in the speed of the wire for a given pump setting will vary

the weight of the sheet being formed. For instance, if the throwing on of the winder caused a decrease in speed, a heavier sheet would be formed for several minutes and then after the winder was off, a lighter sheet would be made.

PAPER MACHINES WITH A SPEED RANGE NOT OVER 3:1

As previously shown, a speed range of 3:1 may cover machines of all types, and, consequently, motors of various capacities. Assume first a mill having four tissue machines, each requiring 30 horse-power with a range of 2:1. Direct current may be obtained from a generator in the power house or from a motor-generator

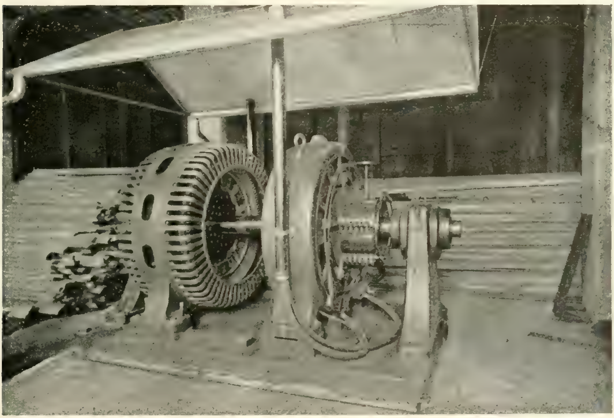


FIG. 5—150 KW SELF-STARTING SYNCHRONOUS MOTOR-GENERATOR SET SUPPLYING POWER TO MOTOR SHOWN IN FIG. 6

set. Assuming each operated at constant voltage, a shunt motor with field control offers the simplest solution. On the other hand, consider a mill with one or two large book machines requiring 125 horse-power or more with a range of 3:1. A similar solution to the above might be made. There are, however, other possibilities worth considering, as for instance, the use of one motor-generator set for each machine. A shunt motor with field control will develop its rated capacity at all speeds with varying torque over the whole speed range, but when applied to a paper machine having a constant torque at all speeds, will be required to develop its full capacity at maximum speed only. A motor with a constant torque characteristic develops its maximum horse-power at maximum speed

only, and, consequently, would make a cheaper motor to apply to a paper machine than one with a constant horse-power characteristic.

By using one motor-generator set for each machine, it is possible to vary the voltage of the generator, and, consequently, the armature voltage of the motor to obtain the desired speed range. It is necessary, however, to separately excite the fields of the generator and motor and also to maintain the motor field at a constant value. The motor speed will vary in proportion to the change in armature voltage and since the field is constant, will be able to develop the same torque at all speeds. Consequently, the armature current will be approximately constant.

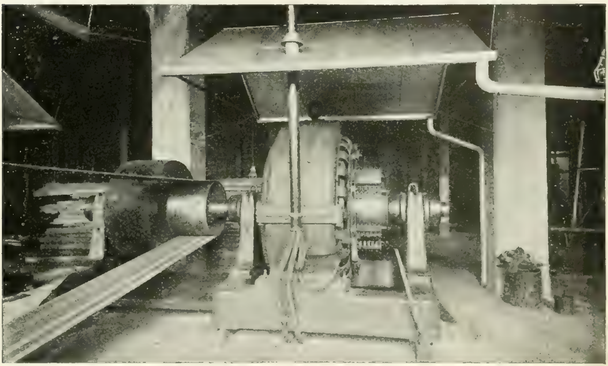


FIG. 6—ADJUSTABLE SPEED MOTOR DRIVING PAPER MACHINE LINE SHAFT

150 hp, 220 volts, 160-800 r.p.m. Although the motor has a speed range of 5:1 by field control alone, a two step pulley was installed so that a speed range of 10:1 could be secured for the line shaft when desired. The control for the motor is in the machine room on the floor above.

Besides a motor with entire field control and one with entire voltage control, there is a motor using a combination of the two which combines some of the advantages of each. To make it more concrete, assume that the first proposition would require a 125 hp motor, 250 volts, 300-900 r.p.m. by field control. The second would call for a 125 hp motor, 250 volts at 900 r.p.m. with a reduction to 300 r.p.m. by decreased voltage. For the combination it is possible to use various amounts of each type of control, but a 125 hp, 250-volt motor at 600 r.p.m., with field control to 900 r.p.m. and voltage control to 300 r.p.m. would make a reasonable design.

The motor-generator would be the same for all of the three motors, since high speed sets have interpole generators as a rule, and these will operate at full-load current over wide ranges in voltage. From a cost point of view, we would expect the motor with field control to be the most expensive, the combination next and the one with voltage control cheapest. It is a well known fact that the ventilation of a motor decreases very rapidly with decrease in speed and, consequently, there is a limit below which a motor cannot carry full-load current continuously. The motor with field control is entirely safe since at one-third speed it would take only about one-third of full-load current; the combination motor would take about two-thirds of full-load current at the lowest speed, while the motor with voltage control will take full-load current. Unless the latter motor is very liberally rated at full speed, it may be necessary to use a larger frame to carry the rated current at slow speed, and in this case the cost of the motors with combination and with voltage control will be the same.

A few percent difference in initial cost should not be the deciding feature, for the performance, or, in other words, the regulation, of the machine is of much more importance. The regulation is a complex quantity since it includes the regulation of the generator and the motor. It is well known that generators and motors at reduced voltages have much poorer regulation than at normal voltage, and also that the regulation of motors by field control is nearly the same at all speeds. It is seen, then, that the regulation obtained by field control will be best, and that by voltage control poorest. If the motor with field control had six percent regulation at maximum speed, it would have about two or three percent at minimum speed due to the reduced current. If the regulation of the motor with combination control is five percent at maximum speed, it will be about three percent at normal speed; then as the voltage is decreased, the regulation will gradually become poorer. The best regulation of the motor with voltage control occurs at highest speed.

As would be expected, the extreme high and low speeds are seldom used for manufacturing paper, and most of the paper is made over the central portion of the speed range. It is seen, then, that the regulation obtained with the combination control gives the best regulation at the average running speed, besides having very good regulation over the whole range. Although the above considered a speed range of only 3:1, practically the same reasoning may

be applied to propositions requiring a range of 7:1, although for this range the cost of motors for field control becomes almost prohibitive and the advantages of the combination control become still more marked.

CONTROL

Besides the starting apparatus for the motor-generator set, the control consists principally of a panel for the generator and exciter, and one for the motor with the starting switches, relays, etc. It should be possible to start, stop, speed up and slow down the motor from the machine room. This may be accomplished entirely by push-button control if desired, or buttons may be used simply for stopping and starting, and the field rheostats placed in the machine room. The control should be so arranged that if the motor is stopped and then started by pushing the start button, the motor will automatically come to the speed at which it was previously running. The number of operating speeds required depends principally upon the speed range and the type of machine. For small speed ranges 50 points are ample, while for the larger ranges 90 to 100 are required. These points, instead of dividing the operating range into equal increments, should divide it into proportional or progressive increments so that the same percentage variation is obtained at the upper limit as at the lower limit. The speed of the paper machine is usually checked by taking the r.p.m. of one of the dryers, or the lower calender roll, but a very simple speed indicator is obtained by driving a magneto-generator from the main shaft and using with this a voltmeter calibrated in feet per minute. This meter may be placed near the push button so that the speed can quickly be brought to any desired value, thus saving the time of adjusting and checking.

It should not be understood from the preceding discussion that a law can be laid down stating the best type of drive for any given machine, for there are often many local conditions which have to be considered, and this article aims only to point out a few of the items which should be taken into consideration.

BORING MILL DRIVE

J. HENRY KLINCK

IT IS not always possible to make a direct comparison between belt and motor-driven equipments. As a consequence, items of major importance in the comparison of the two methods are often overlooked in splitting hairs over minor details. The possibilities of any given application can usually be analyzed, as has been done with the particular case given below, and some very interesting comparisons can be made with the data thus obtained. The study of the boring mill under consideration is used to show an actual example of what has been done in practice.

The ordinary method of changing the speeds of machine tools by shifting belts on the various steps of cone pulleys, has mechanical limitations which render it unsuitable for use where many steps are required over a considerable range. The use of what is called a speed box in connection with the cone pulley is of considerable assistance in such cases. The speed box consists of a group of gear trains and clutches, the combination of gears in action at a given time depending on the particular clutch then in service. In the tool under consideration, Fig. 1, the speed box contains:—

Two shafts.
Six gears, two with sleeves.
One double end clutch.
Two single end clutches.
Two sleeves.
Four bearings for the shafts and gears.
Two clutch levers, with supports, supporting pins, clutch blocks, latch pins and other accessories.

These parts are so assembled that it is possible by means of clutches to obtain four changes in speed, the ratings being:—

Clutch 1—1 to 1.00
Clutch 2—1 to 2.25
Clutch 3—1 to 5.00
Clutch 4—1 to 12.50

On the belt-driven mill, shown in Fig. 1, the relation between the diameters of the cones on the four-step cone pulley is such that the speed increment is about 25 percent for each step. This gives the following possible changes in speed of the boring mill table by shifting the belt on the cone pulley alone:—

Step 1—1 to 1.00
Step 2—1 to 1.25
Step 3—1 to 1.55
Step 4—1 to 1.95

This may be done in connection with any of the four gear combinations in the speed box. The total number of independent

speeds which can be obtained is, therefore, sixteen. These are approximately as shown in Table I. This table shows that the speed

TABLE I

SHOWING SPEED RATIOS WITH PULLEYS AND CLUTCHES

Belt Position	Clutch 1	Clutch 2	Clutch 3	Clutch 4
Step 1	1.00	2.25	5.00	12.50
Step 2	1.25	2.80	6.25	15.50
Step 3	1.55	3.60	7.75	19.40
Step 4	1.95	4.50	9.80	24.40

range obtainable is practically *1* to *25*. Any speed range desired can be obtained, as this feature is one of design. An increase in the range will, of necessity, require a larger jump in passing from

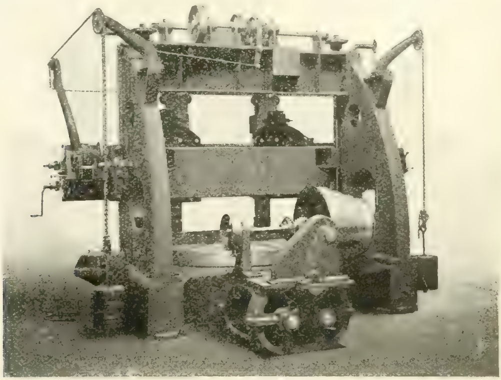


FIG. 1—BELT DRIVEN BORING MILL WITH SPEED CONE

one speed to another or an increase in the number of gears and clutches used.

By substituting a constant speed motor for the countershaft, and four pairs of gears—eight in all—for the cone pulley, the same changes in speed can be obtained, but in place of shifting the belt it is necessary to change the gears. Such an installation is shown in Fig. 2. By thus doing away with the cone pulley, a tool is obtained that can be placed anywhere in the shop without reference to any line shaft. This is of particular advantage where crane

service is available. The constant losses of a belt-driven transmission system are eliminated, as the motor is running only while the tool is operating. The speed range is identical with that in the belt-driven tool and the individual speeds are the same.

The use of the speed box in connection with a motor having a speed range of *1* to *2*, is shown in Fig. 3. This equipment is operated by means of a reversing type drum controller having 16 running positions in the forward and six in the reverse direction. Each of these is available in combination with any of the four

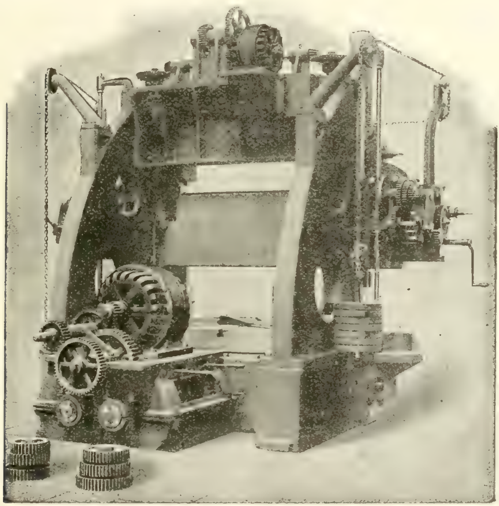


FIG. 2—CONSTANT SPEED ELECTRIC DRIVE ON BORING MILL. MAIN DRIVE 15 HP, 1120 R.P.M. SQUIRREL CAGE INDUCTION MOTOR

speed-box ratios. The speeds that are possible with this arrangement are given in Table II. On any individual clutch there is thus available a speed variation of *1* to *2*, in 15 independent steps, each speed being approximately five percent higher than the one immediately preceding it. By the use of the four clutches, a practically unbroken speed range of *1* to *25* is obtained in *16* steps.

A tool equipped with a motor having a speed range of *1* to *4* is shown in Fig. 4. The omission of the speed box makes the entire

connection between the motor and the driving mechanism of the tool consist of:—

Two shafts
Four gears
One double end clutch
Two bearings
One clutch lever and accessories

The motor drives the main shaft either through the intermediate gear, or through the back gears, depending on the position of the clutch. With only two mechanical speed changes in the ratio

TABLE II

SHOWING SPEED RATIOS WITH MOTOR HAVING SPEED RANGE OF 1:2 AND 16-POINT CONTROLLER, WITH FOUR CLUTCHES

Controller Position	Clutch 1	Clutch 2	Clutch 3	Clutch 4
1	1.00	2.25	5.00	12.50
2	1.05	2.36	5.25	13.10
3	1.10	2.48	5.55	13.80
4	1.15	2.59	5.75	14.30
5	1.20	2.70	6.00	15.00
6	1.25	2.81	6.25	15.60
7	1.30	2.93	6.50	16.20
8	1.36	3.06	6.80	17.00
9	1.42	3.20	7.10	17.70
10	1.49	3.35	7.45	18.60
11	1.56	3.51	7.80	19.50
12	1.64	3.69	8.20	20.50
13	1.72	3.87	8.60	21.50
14	1.83	4.11	9.15	22.80
15	1.92	4.32	9.60	24.00
16	2.00	4.50	10.00	25.00

of *1* to *1* and *1* to 5 there is available a speed range of *1* to *20* with a motor speed range of *1* to *4*. Thus by the simple addition of a clutch, a shaft and a pair of back gears, the available continuous range of speed is increased from four to twenty times normal. The speeds available in this case are given in Table III. In this case the total speed range is *1* to *20* instead of *1* to *25*, as in the previous instances. The speeds obtainable are, with the single exception of the gap between the clutches, each one an increase of ten percent over the one immediately preceeding. While the table shows a gap at this point, in practice this gap can be entirely eliminated either by operating the motor over a slightly greater range than *1* to *2*, or by making the ratio of the back gear combination slightly less than *1* to *5*.

While the total number of speeds available with a motor having a range of *1* to *4* and no speed box, is less than with the combined *1* to *2* range motor and speed box, this is in no sense a detriment from an operating standpoint, as the latter combination gives speed increments smaller than are usually needed in practice. With the *1* to *2* motor, the speed increments are five percent, while with the *1* to *4* motor the increments are ten percent. The speed range on the average work is from 15 to 30 feet per minute. When running at 20 feet per minute, a five percent increase in speed gives 21 feet, and a ten percent increase gives 22 feet. It is difficult to imagine actual operating conditions under which ten percent increments will not answer all requirements; if, however, such conditions do exist, the *1* to *2* motor with the speed box is preferable. The general relation existing between the different types of equipment is as follows:—

TABLE III

SHOWING SPEED RATIOS WITH MOTOR HAVING SPEED RANGE OF 1:4 AND TWO MECHANICAL SPEED CHANGES

Controller Position	Clutch 1	Clutch 2
1	1.00	5.00
2	1.10	5.50
3	1.20	6.00
4	1.30	6.50
5	1.40	7.00
6	1.55	7.75
7	1.70	8.50
8	1.85	9.25
9	2.05	10.25
10	2.25	11.25
11	2.50	12.50
12	2.70	13.50
13	3.00	15.00
14	3.30	16.50
15	3.65	18.25
16	4.00	20.00

The Belt-Driven Mill with the speed box has a speed range of *1* to *25* composed of four independent series with a variable ratio between series. Each series consists of four speeds, with increments of 25 percent, making 16 speeds in all. The method of control is by means of shifting belt or clutches separately or together.

The Constant Speed Motor with four sets of gears gives a speed range of *1* to *25*, with the same speed characteristics as the

belt-driven tool; the change in speed in this case is affected by changing gears or shifting clutches together or separately.

The 1 to 2 Adjustable Speed Motor with the speed box, gives a speed range of *1* to *25* in 63 steps. These steps occur in four series, corresponding to the four clutches of the speed box; each series contains 16 speeds corresponding to the 16 controller notches. The speed increment is five percent for the first 31 steps, a slightly

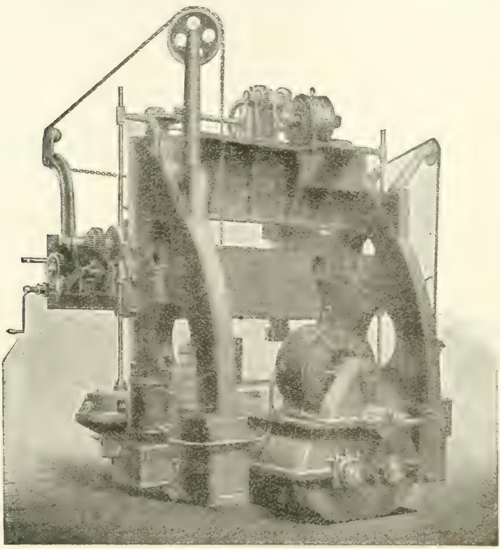


FIG. 3—BORING MILL WITH MOTOR DRIVE. 2 TO 1 SPEED RANGE. MAIN DRIVE 15 HP, 625 TO 1250 R.P.M. DIRECT CURRENT SHUNT MOTOR

larger increment on the 32nd step, and five percent for the last 31 steps.

The 1 to 4 Adjustable Speed Motor, without the speed box gives a speed range of *1* to *20*, consisting of one continuous series of 31 steps with ten percent increments. The method of control is by means of a drum controller and two clutches, the controller giving 16 speeds with each clutch.

There is no dispute regarding ease of control. With the motor-driven tool the operator can start or stop the tool or change the

speed without having to leave his working position, except to throw the clutches.

The illustrations here given show standard equipments made by the Niles Tool Works. Each motor-driven mill of this type has a motor mounted on top for raising and lowering the crosshead. On the belt-driven mill the position of the crosshead is adjusted by means of a belt, but, as shown in Fig. 1, there are pads for the application of a bracket should it be desired to convert the mill

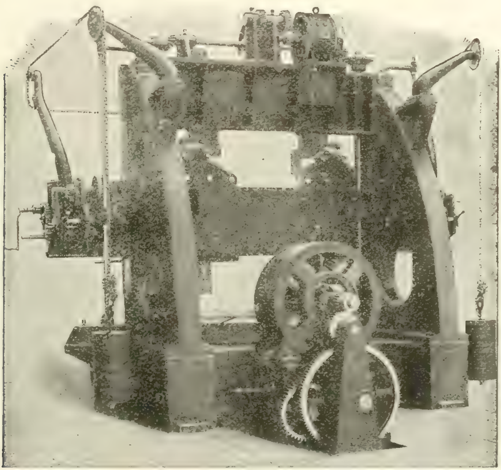


FIG. 4—BORING MILL WITH MOTOR DRIVE, 4 TO 1 SPEED RANGE. MAIN DRIVE 12.5 HP, 400-1600 R.P.M. INTERPOLE MOTOR

to motor drive at a future time. Practically all modern heavy belt-driven tools are provided with pads of this kind upon which to mount the motors, so that the change to motor drive can easily be made.

MOTORS FOR DRIVING THE MAIN ROLLS OF STEEL MILLS

BRENT WILEY

MR. JULIAN KENNEDY, one of the foremost steel mill engineers, has said, "The success of the steel industry in the past has depended upon push, energy and daring; but in the future it will depend upon the economies and refinements of the art."

One of the most important matters now receiving the consideration of steel manufacturers is the question of reduction of power costs; for, while the cost of power for rolling steel is only a small percentage of the total cost of its manufacture, the aggre-

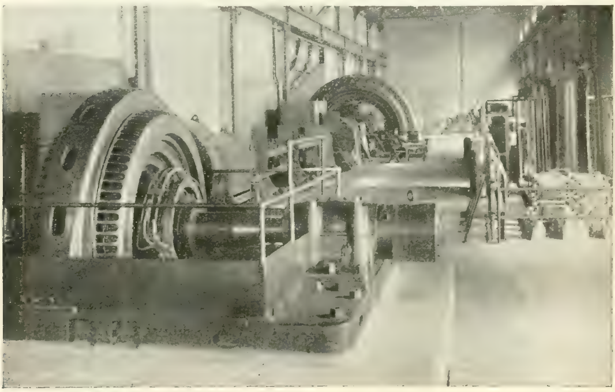


FIG. 1—3 200 HP AND 650 HP MOTORS DRIVING MAIN ROLLS OF 18-INCH MERCHANT MILL, SHOWN IN FIG. 7

gate cost of fuel represents a large amount, due to the exceedingly large tonnage of the mills.

There are two efficient methods of accomplishing a reduction of power costs:—

First, by the installation of gas engines using blast-furnace gas, connected to drive electric generators.

Second, by the installation of low-pressure steam turbines operating on exhaust steam from the mill or other power engines, for driving electric generators.

It is not practical to connect the gas engine or the exhaust tur-

bine direct to the rolling mill, but the best solution is to transmit by means of electricity the cheap power thus obtained. This requires motor drive on the main rolls. In some cases, especially with small plants, the advantages of this form of cheap power for supplying electric drive to the auxiliary apparatus, are sufficient to warrant the extra first cost, even to the extent of abandoning the old engine-driven power apparatus.

The advantages of electric drive are: constant and regular torque; more reliable drive, less breakage of couplings, pinions, etc.; less room required, by reason of absence of boilers, pipes, etc.; easy adaptation of motors to mill; easy distribution of power by means of electric cables, instead of steam or gas pipes; easy and simple control of the power; centralized power generation; less labor; lower fuel costs; less oil and other stores, and the use of gas engines of medium size in the power station. In addition, the output may be

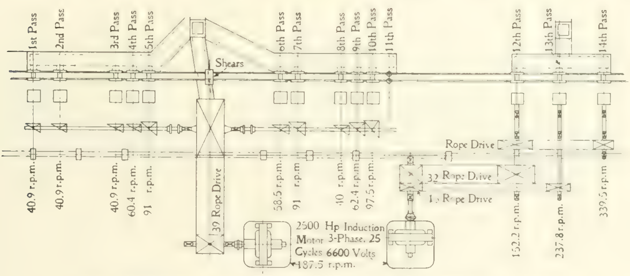


FIG. 2—SKELP MILL, NATIONAL TUBE CO., LORAIN, OHIO

increased at times on account of the economical speed variation that can be obtained with motors, where it is desired to finish the light material at a higher speed than the average product. Alternating-current motors can be designed with windings for two speeds, and sometimes two units with cascade connections are used to give the required speed changes.

Electric drive for the main rolls of steel mills has also a great many advantages that cannot be capitalized directly but which will be very effective in the furthering of this comparatively recent development. One of the principal incidental advantages is the facility afforded for obtaining accurate records of the power required, such as that shown in Fig. 3. The exact operating conditions can be definitely determined at any time by means of indicating and inte-

grating meters. This condition is quite in contrast with the problem of power readings for steam engine drive. The many automatic and protective features of the auxiliary motor drives also permit a better arrangement of the mill and more economical operation by reducing the number of operators required.

During the past four years approximately 150 000 hp in large motor units for the operation of rolls have been installed in steel mills, including drives for blooming, billet, rail, structural, universal, plate, wire, merchant, re-rolling and sheet mills. Test data from these various mills will do much to advance the art of rolling. The power requirements can be studied in detail and the reduction schedule can be worked out for greatest economy of power and time. Power instruments give indication of any disorder in the mill proper, thus enabling the mill foreman to prevent excessive friction loads and excessive wear of parts due to poor alignment, excessive thrust and bearing pressure.

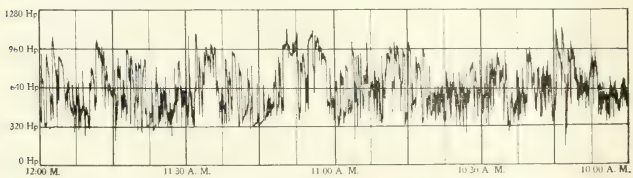


FIG. 3—GRAPHIC WATTMETER CURVE FOR 1 200 HP MOTOR ON ROLLS OF SHEET MILL, SENECA IRON AND STEEL CO.

The question of commercial efficiency is the principal item to be considered, and it is quite complicated owing to the fact that as conditions vary greatly in different plants a separate analysis must be made of almost every case.

The United States Steel Corporation and many other steel companies are making a careful study of this particular subject in order to improve the economy of their present works. In many plants it is not practicable to consider the gas-engine proposition. The number of furnaces may not be sufficient to insure reliable operation or the plant may not include blast furnaces; or again, the first cost of the installation may be prohibitive, being very much more expensive than a low-pressure steam turbine equipment of equal capacity. On the other hand, by the use of the exhaust steam turbine taking steam from non-condensing engines, an increase of 75 percent of the power developed by the engine can be obtained without additional fuel consumption.

The several mill plan views shown give an idea of different mill arrangements and methods of drive. In several merchant-mill propositions a motor for each stand of rolls has been considered, but in every case it has been found best to reduce the driving units to two, from a standpoint both of first cost and of mill design. It will be noted that in the Indiana Steel Company's merchant mills the second motor is used to drive the finishing pass only. In existing merchant mills, where all of the roll trains are connected together and consequently all are running at the same speed, it will often be found advantageous to install a motor to drive the last set of rolls or perhaps the last two, thus giving an opportunity to speed up these rolls and thereby get the long material out of the mill more quickly. This is especially true in the smaller mills (eight inches to ten inches). The Illinois Steel Company tried out this scheme in

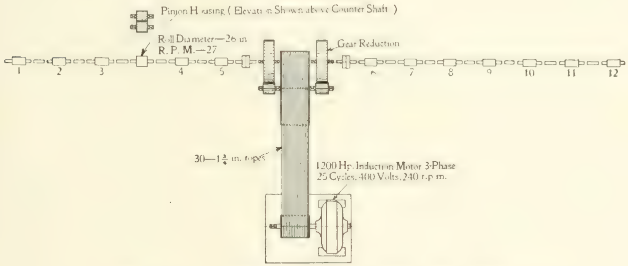


FIG. 4—SHEET MILL, SENECA IRON AND STEEL CO., BUFFALO, N. Y.

Both top and bottom rolls of No. 3 mill are driven. On other mills, the bottom roll only is driven.

its Milwaukee eight-inch merchant mill with splendid success, increasing the output several percent due to the more nearly continuous operation of the mill.

Direct-current motors have been installed in some cases in order to secure the advantage of speed variation. The present tendency is, however, toward the exclusive use of alternating-current at voltages of 2 200 to 6 600 volts, at 25 cycles, three-phase. The lower frequency allows much cheaper construction of large-sized slow-speed motors, while the higher voltages afford many advantages in the distribution of power in large plants. The motors are of the induction type with phase wound secondaries.

In estimating a motor for this type of work a load diagram of the torque required during a complete cycle of operations is

first drawn up as shown in Fig. 6. Such a load diagram gives the exact nature of the load conditions including variation of load and the time element, and this information is essential in calculating the proper capacity of the motor and the necessary fly-wheel effect to be included in the system. The full line in Fig 6 shows the calculated load diagram for the motor driving the main rolls of the 18-inch merchant mill of the Indiana Steel Company. This motor, as shown in Fig. 7, drives rolls for eight passes. The rolls of the ninth or finishing pass are driven by a smaller motor which develops approximately 660 horse-power for twelve seconds in each 20-second period. The diagram shows a maximum requirement of approximately 4 500 horse-power and a minimum of less than 1 000 horse-

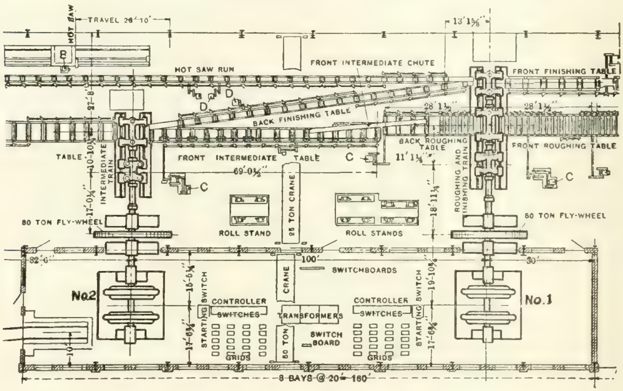


FIG. 5—LIGHT RAIL MILL, SOUTH WORKS, ILLINOIS STEEL CO., SOUTH CHICAGO, ILL.

power during each 20-second period. Owing to the fly-wheel effect, the load on the motor is slightly reduced or equalized as shown by the dotted line. In this particular case the power required is not subject to extreme variations, and moreover the cost of power is low. A comparatively low fly-wheel effect was, therefore, considered advisable. In case the driving power fluctuates between wide limits in very short periods, a larger fly-wheel effect is preferable, especially where the cost of power is an important item.

The motor is designed to perform the work as shown by the estimated load diagram at a safe temperature rise, or in other words, is figured on an intermittent load basis, and thus the con-

tinuous rating given the motor is really an arbitrary one. The design of the motor is made according to the local conditions. For instance, where rope drive is used, giving flexibility between the motor and mill shaft, it is not necessary to make the motor excessively strong; the speed can be moderate instead of exceptionally

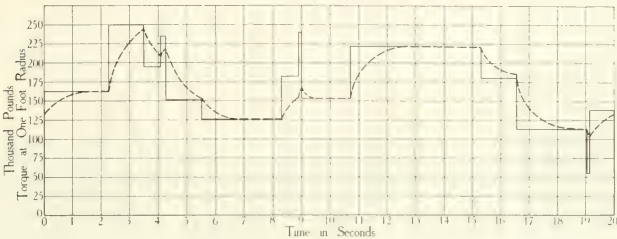


FIG. 6—ESTIMATED LOAD CURVE FOR 3 200 HP MOTOR

This diagram represents a cycle of 20 seconds duration and continues by repetition.

Full Line—Load diagram.

Dotted Line—Motor load with fly-wheel effect of three million pounds at one foot radius. Motor speed with 184 000 lbs.-ft. torque is 91.5 r.p.m. Slip, 10 percent.

slow as is generally the case when the mill shaft is driven direct, and the rope sheaves give opportunity to place the necessary fly-wheel effect outside the motor, a good point where exceptional mechanical strength of motor is not actually required.

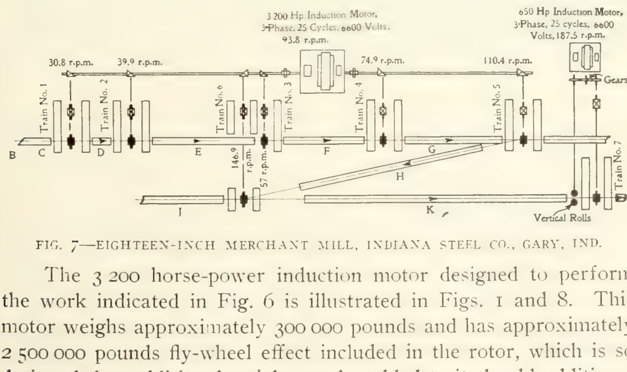


FIG. 7—EIGHTEEN-INCH MERCHANT MILL, INDIANA STEEL CO., GARY, IND.

The 3 200 horse-power induction motor designed to perform the work indicated in Fig. 6 is illustrated in Figs. 1 and 8. This motor weighs approximately 300 000 pounds and has approximately 2 500 000 pounds fly-wheel effect included in the rotor, which is so designed that additional weight can be added to it should additional

fly-wheel effect be desirable. The illustrations give a good idea of the general mechanical characteristics of the machine.

The primary (or stator) is of the open-slot type, wound with form-wound coils made of rectangular strap copper, thoroughly insulated and impregnated before winding. The coils are supported rigidly at the outer ends by means of an insulated steel ring fastened to the frame by a number of strong brackets. Means are provided for adjusting the stator vertically and horizontally at right angles to the shaft for adjusting the air gap, and also for moving the stator parallel to the shaft to allow for inspection or repairs.

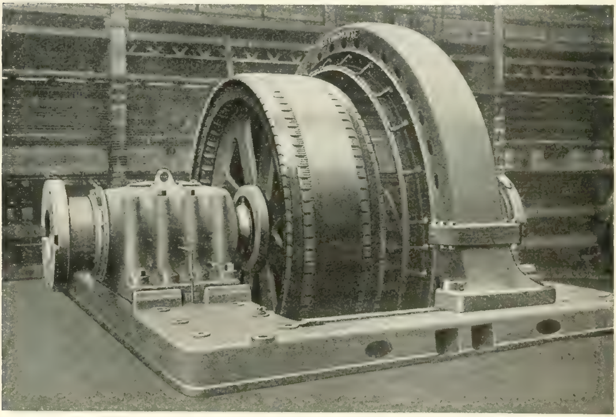


FIG. 8—3 200 HP ROLL MOTOR, WITH STATOR MOVED ASIDE TO ALLOW INSPECTION OF ROTOR

The slot construction of the secondary, while of the partially enclosed type thus tending to compensate for the effect of the unusually large air gap provided in such motors, permits the use of a completely insulated form-wound coil. The overhanging tooth of the laminations assists materially in retaining the fibre wedge in place. This is of especial importance in the secondary as it is the revolving part. Band wires for retaining the overhung portions of the coil in place are objectionable, particularly from the standpoint of repairs when all work must be done in the field. A sectional ring is used in place of band wire on this machine as shown in Fig. 8.

Thrust bearings are provided whose object is to care for ordinary thrusts due to wear of coupling boxes, but not excessive thrusts due to breaking of mill spindle. To provide for these thrusts, the rotor is sometimes arranged to have a lateral movement of several inches without damage to any part except the holding bolts of the thrust bearings. Provision is made for shifting the entire brush rigging with the rotor so that the brushes will always stay on the collector rings. The thrust bearings are located at the end of the shaft opposite the coupling and are held by two bolts which are turned at one place to provide a breaking point. The bolts which pass through the bearing pedestal, together with the bed

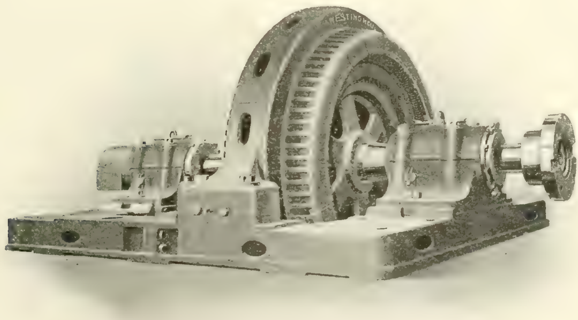


FIG. 9—660 HP ROLL MOTOR, OPERATING FINISHING ROLLS, 18-INCH MERCHANT MILL

plates and parts, are designed to withstand the breaking stress of the holding bolts without injury.

The control outfit for this motor consists of two identical three-pole, single-throw, interlocking primary line switches with oil immersed contacts, (one switch for each direction of rotation), a group of magnet switches with the necessary secondary resistance and with current limiting relays, a reversing drum-type master switch, and shunt and series transformers for the relays. The line switches are so interlocked that only one can be closed at a time, and neither can be closed while the secondary switches are in other

than the off position, that is, unless the secondary resistance is all in circuit. The line switches can be operated from the control pulpit or from the motor house. When the control circuit is open in the motor house the master switch and line switch operating mechanism in the pulpit are inoperative. Should the line switch be opened for any cause, or should the control circuit fail, all switches are immediately opened.

Motors in this service are seldom reversed, these cases arising only where material curls and tends to form a collar or for other reasons forms a cobble in the rolls. They start with resistance in the secondary circuit. As the speed increases this resistance is cut

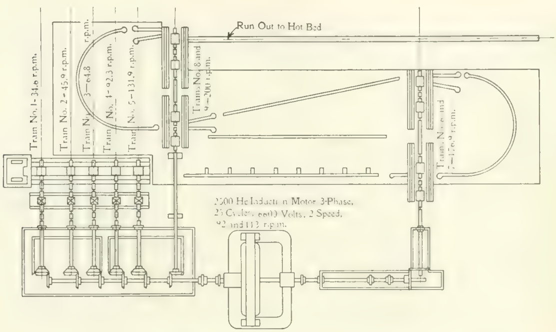


FIG 10—TEN-INCH MERCHANT MILL, INDIANA STEEL CO., GARY, IND.

out by means of the magnet switches, each of which is under the control of the master switch, but is so connected as to automatically limit the current to a pre-determined value and also limit the current to this same value at any time during starting, except that the first notch of the controller is arranged to give sufficient torque to start the motor. The motors are operated in most cases with a permanent resistance in the secondary circuit, and provision is made for adjusting this resistance to cause a slip suited to the load condition.

Special provision must be made for stopping large motors with high fly-wheel effect, otherwise the momentum will keep the rotating part in motion for hours. Where direct current is available it can be used to excite the primary windings of the motor, and the energy generated in the secondary can be dissipated in resistance. A sec-

ond method is to reverse a phase of the primary circuit and by means of a suitable auto-starter impress on the primary about one-half the normal voltage. The latter method, "plugging" the motor with half voltage, will cause a very quick stop.

The two-speed motors noted in some of the diagrams have two windings on both the primary and secondary and it is possible with such an arrangement of windings to give three speeds, such as 120, 180 and 240 revolutions per minute.

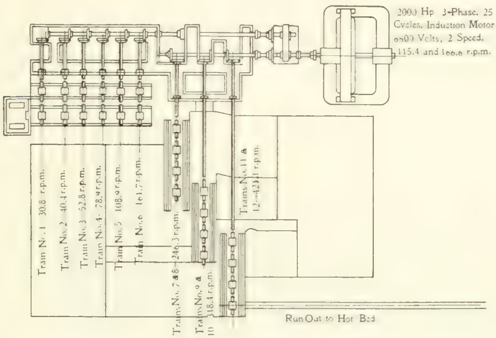


FIG. 11—TWELVE-INCH MERCHANT MILL, INDIANA STEEL CO., GARY, IND.

The electrification of the rolling mills has just begun. There is a great field for electric drive in the future developments of the iron and steel industries, and there are other applications, such as the electric furnace for steel refining, which are sure to give electricity a far more important place in these industries than it has held in the past.

ALTERNATING-CURRENT ELEVATOR MOTORS

W. H. PATTERSON

AN electric elevator motor must develop high starting torque to overcome friction and accelerate the load. After the elevator has been brought up to speed, the torque required for hoisting the car drops off to less than half that required for starting, as it is then necessary only to overcome running friction and hoist the load itself.

Both squirrel-cage motors having high resistance end rings and wound secondary slip-ring motors are used for operating elevators. The characteristics of a properly designed squirrel-cage induction motor with high resistance end rings make it especially adaptable

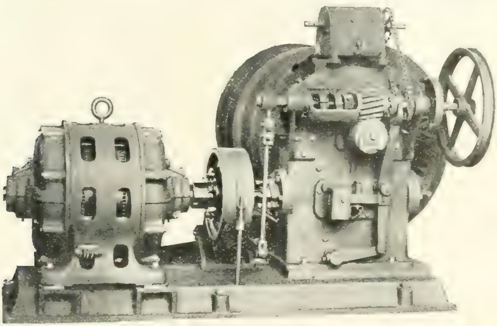


FIG. 1—SQUIRREL-CAGE ELEVATOR MOTOR, AND HOIST MECHANISM

to the service. Such a motor exerts its maximum torque at starting, and as the torque decreases the speed of the motor increases. The motor can be connected directly across the line by means of a simple reverse switch thereby replacing the more expensive controller and resistance necessary for controlling a phase-wound motor. The brushes, brush-holders and collector rings of the phase-wound motor are also eliminated.

Squirrel-cage motors are used for operating freight elevators having a capacity of 3 000 to 8 000 lbs. at speeds of from 25 to 100 feet per minute, and passenger elevators having a capacity of 1 000 to 3 000 lbs. at speeds of 100 to 150 feet per minute. Owing to the high torque required at starting, the motor starts at slow

speed. The acceleration of the car is smooth and gradual, not jerky, although full voltage is at once impressed upon the motor.

These motors will develop approximately double full-load torque at starting, with approximately 2.5 times full-load current. To obtain high starting torque with low current at the start requires high resistance end rings, which in turn produce a large slip. It has been found by experience that the best results are secured by a slip of as high as 20 percent.

A typical performance curve of a high resistance end ring squirrel-cage cage motor for elevator service is shown in Fig. 2. This curve indicates a full-load power-factor of 80 percent and a full-load efficiency of 71 percent. While the apparent efficiency of these motors is low they should not be compared with constant

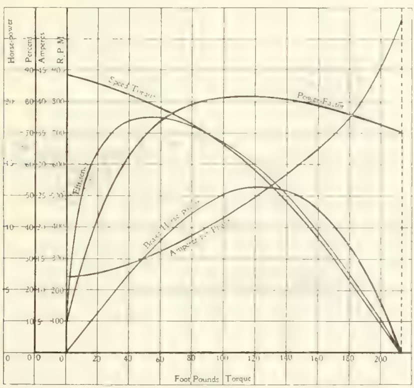


FIG. 2—CHARACTERISTIC CURVES OF SQUIRREL-CAGE ELEVATOR MOTOR

speed motors, as the possible variations in efficiency of the elevators themselves are very great due to the friction of the gears and cables on the drum, etc., and efficiency is, therefore, not an important feature in an elevator motor. The apparent efficiency of squirrel-cage elevator motors, however, when compared with slip-ring elevator motors is very good.

The starting torque of these motors equals their pull-out torque, as shown on the curve, so that they exert their maximum torque when required in elevator service, i. e. at starting. This is a very important feature in the choice of an elevator motor. If the resist-

ance of the rotor is low enough that the starting torque is less than the pull-out torque, the efficiency will be slightly improved, but the motor will not start as heavy loads; moreover, as the required torque decreases after starting, the motor torque increases, causing a very sudden and disagreeable acceleration.

The power-factor at starting varies from 70 to 80 percent and the full-load power-factor from 80 to 83 percent. The high power-factor at starting is a very desirable feature as the power-factor of the ordinary squirrel-cage induction motor at starting is from 55 to 60 percent. The simplicity and performance of the high resistance end-ring motor makes it an excellent source of power for elevator service.

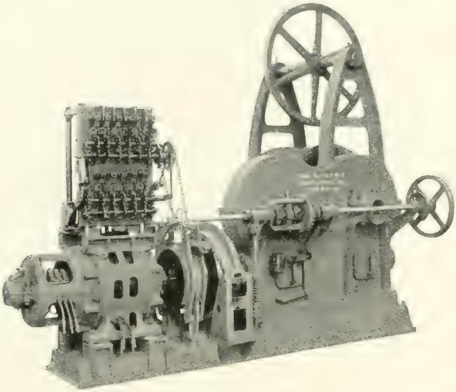


FIG. 3—WOUND-SECONDARY ELEVATOR MOTOR, AND HOIST MECHANISM

Squirrel-cage elevator motors are made in sizes up to a maximum of eighteen horse-power, this being the practical limit in size of these motors owing to the starting current. Elevators requiring larger motors are ordinarily for higher speeds, which involve a longer period of acceleration, thus necessitating a wound rotor with external resistance in the secondary. The rate of cutting out this resistance and thus accelerating the motor may be regulated at the controller.

The wound-secondary induction motor has high starting torque characteristic and speeds satisfactory for operating elevators of all capacities up to a maximum speed of 250 feet per minute. Elevators operating at higher speeds are practically always

two speed machines and this feature immediately eliminates the alternating-current motor from a practical standpoint, as with any given amount of resistance inserted in the rotor circuit the speed will vary with the load. Thus, on high speed elevators running from 250 to 600 feet per minute, direct current motors are always used. Another feature that limits the use of alternating current to elevators operating at speeds of not over 250 feet per minute is that in order to accomplish dynamic breaking of an induction motor for automatically slowing down the elevator car, a small motor-generator set is necessary to supply direct-current excitation to the primary. Therefore in driving all modern high speed electric elevators direct-current motors are used.

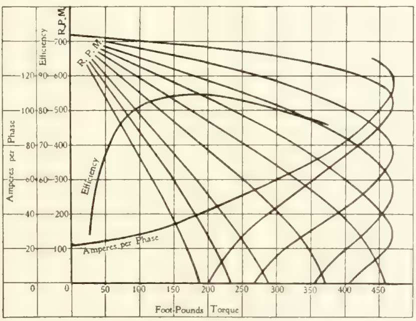


FIG. 4—CHARACTERISTIC CURVES OF WOUND-SECONDARY ELEVATOR MOTOR, AT VARIOUS CONTROLLER POINTS

A typical performance curve of a wound secondary motor for elevator service is shown in Fig. 4. These motors will develop approximately twice full-load torque with about twice full-load current. Practically all alternating-current elevator motors are rated for continuous operation at full load for one-half hour with a temperature rise not exceeding 55 degrees. This is the standard adopted by the American Institute of Electrical Engineers. This nominal rating is of slight importance, however, unless the characteristics of the motor are such that a large starting torque is produced. For example, assume an elevator having a net load of 1 900 lbs. running at a speed of 110 feet per minute:—

$$\text{Hp} = \frac{\text{Lbs. Load} \times \text{Ft. per Min.}}{33\,000 \times \text{Eff. of Elevator Mech.}} = \frac{1\,000 \times 110}{33\,000 \times 0.50} = 12.6$$

The assumed elevator efficiency, 50 percent, is that generally used by all elevator manufacturers. Assuming a full-load speed of 720 r.p.m. for the motor:—

$$\text{Full Load Torque} = \frac{\text{Hp} \times 5\,250}{\text{R. P. M.}} = \frac{12.6 \times 5\,250}{720} = 92 \text{ Lbs.}$$

It is a safe assumption that the maximum torque at starting

equals twice full-load torque, or 184 pounds, so that a motor should be selected that would have a starting torque at least equal to 184 pounds. After selecting a motor in this manner the service conditions should always be considered to make sure that the operation is not continuous enough to cause the motor to overheat.

CONTROLLER

As stated above squirrel-cage motors of the type described require no controller, as they are connected directly across the line. A drum type reversing switch of the type shown in Fig. 5 is used to control the direction of rotation. The mechanism is contained in a cast iron frame and protected by a sheet metal cover. The drum contacts and the fingers are provided with arc shields. The drum is operated by a hand rope or lever in the elevator car.

A most successful controller for use with polyphase slip-ring elevator motors is shown in Fig. 6. Every operation is performed by this mechanism in a positive manner. The operator has complete control over the starting and stopping of the motor, while the acceleration is performed automatically at a rate that can be adjusted over a wide range at the controller but cannot be altered by any action of the operator in the car. Any part of the controller is accessible from the front and all the parts subject to wear can be readily replaced. The electric contacts are of the quick-break butt type and are protected by arc shields; there are no sliding contacts. All automatic operations are performed by the force of gravity.

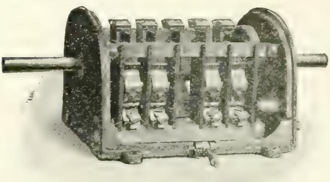


FIG. 5—REVERSING SWITCH FOR SQUIRREL CAGE ELEVATOR MOTOR

The controller consists of a slate panel on which are mounted two rows of switches and their operating mechanism. The switches of the upper row serve to connect the motor primary with the line, and those of the lower row short-circuit the resistance in series with the motor secondary. All switches are alike and interchangeable, five primary switches being used for a three-phase and six for a two-phase controller.

The switches are opened and closed by cams. In closing, each cam acts on its own switch through a buffer spring which serves as a cushion and also compensates for wear. In opening, a lug on the

cam engages a projection on the switch arm and forces the switch open. The movement of a hand rope or lever in the elevator car operates a sprocket attached to the primary cam shaft. A turn of this shaft from the off position closes the primary switches, starting the motor, and simultaneously releases a catch and allows a weight attached to an arm geared to the secondary cam shaft to fall. The weight arm rotates the secondary cam shaft and closes the secondary switches in proper order. The fall of the weight is re-

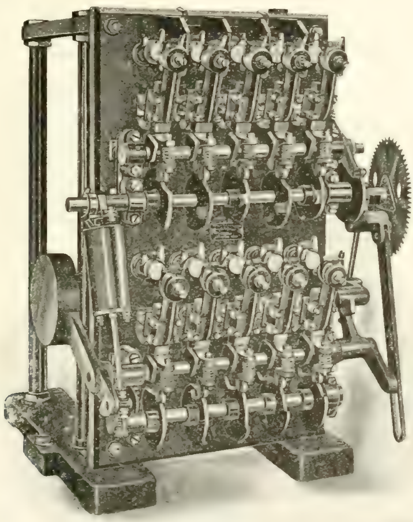


FIG. 6—CONTROLLER FOR WOUND-SECONDARY ELEVATOR MOTOR

tarded by a dash-pot, the piston speed of which can be so adjusted by means of a valve that proper acceleration can be given to the motor. Turning the primary cam shaft in the opposite direction closes the other set of primary switches and reverses the direction of rotation of the motor, the secondary switches always closing in the same order. On turning the controller to the off position the secondary switches are opened, the weight is raised and set ready for the next operation, and the primary switches are opened.

MOTOR DRIVE IN LAUNDRIES

R. D. NYE

THE application of electric motor drive to laundry power work presents a broad and interesting field. The development of the steam laundry has been so rapid that the attention of those working in the field seems to have been centered heretofore almost entirely on producing machinery and carrying on the business. For this reason, possibly, the advantages of motor drive have been overlooked, so that in the majority of plants to-day the various machines are driven by an engine connected to them through many shafts and belts.

To the manager of the plant using this method of drive the installation of a generator and motors to replace the old system which is performing the work in an apparently satisfactory manner generally seems an unwarranted expense. If such plants can purchase the necessary electric power, the motors alone can be installed at a much lower cost, due to elimination of the generating equipment. They thus secure the advantages of electric drive, and quite often they also secure the power to run the plant at a lower cost than the total actual cost of generating it themselves.

Almost every town which is large enough to justify central station day service has a power driven laundry, and wherever these two are found together the mutual advantages of the electric drive should be realized. The problems to be solved in introducing the drive into such plants are interesting, because of the close figuring which must be done, and the conclusive proofs which must be presented by the central station power solicitor or the motor manufacturer's representative, to justify the expense of a change from the old system of steam or gas engine drive. Of course each case will present special problems and this article will attempt to cover only such points of interest as are generally common to all such cases.

The first question which always arises when undertaking to lay out a plant is where and how to apply the power. A great number of combinations are possible in any plant, ranging from one large motor to a number of smaller motors. The expense of a large number of motors or of individual drive can be justified only by reduced power consumption or labor charges or by increased output. When it is borne in mind that all individual motors for laundry machines

are small and that the efficiency of such units is comparatively low, it is evident that larger motors of higher efficiency, when arranged to drive groups of machines which must be operated at the same time, will afford as efficient an installation as individual drive, and will be cheaper.

The question of grouping depends, of course, upon the relative location of the machines and the amount of shafting required to drive them. A good example of an efficient group is shown in Fig. 1, where a two horse-power motor is driving a set of shirt ironing machines and blower, which, if individually driven, would require a larger total amount of power. There would be no advantage in individual drive here, because a piece of work passes through each of these machines in order, and hence the operation of any one depends upon all the others. The shafting in laundries is also of light weight and operates at low speeds, so that the amount of power consumed in driving it is small.

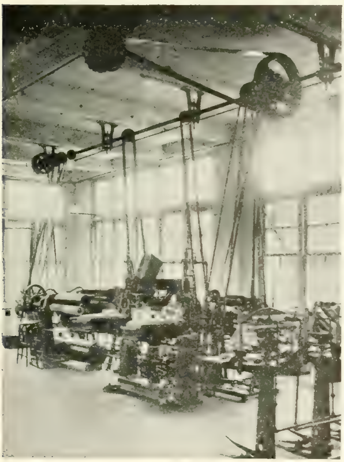


FIG. 1—GROUP OF SHIRT IRONING MACHINES AND BLOWER, DRIVEN BY A TWO HORSE-POWER MOTOR

At this point it is well to bear in mind the three main divisions of the work, namely, washing, drying and ironing. A number of the washers are generally installed, some of which are used all the time and the balance are held in reserve for the rush days of the week. Also one or more centrifugal extractors will be in use all of the time and others held in reserve, in connection with the washing machines. These extractors generally require two or three times the amount of torque to start them that is necessary to run them when up to speed, and often the starting torque requirement determines the size of motor when individual drive is used. Inasmuch as the extractors must always run in connection with the washers, a grouping of two or more washers and an extractor works out very well. Such a group is shown in Fig. 2 where three

36 by 54-inch washers and a 26-inch extractor are all driven by one five horse-power 1 120 r.p.m. motor, the extractor being located at the far end of the line of washers and not shown in the photograph. The five horse-power motor takes care of this group of machines very well and actual test shows that it carries a slight overload only at the time of starting the extractor, whereas a 7.5 horse-power motor was specified originally for this group on the basis of the amount of power required by each machine. Three such groups, each consisting of three washers and an extractor, are in use in this

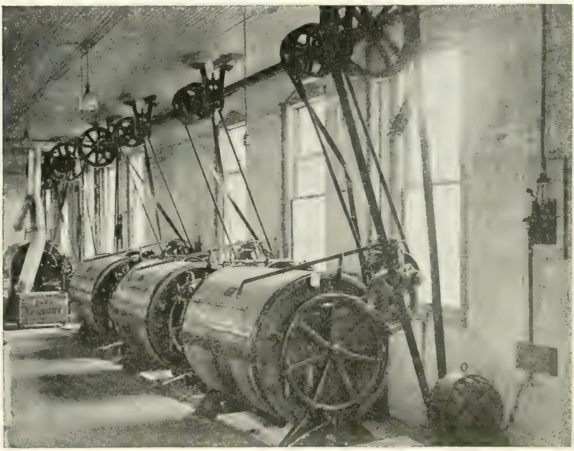


FIG. 2—FIVE HORSE-POWER MOTOR DRIVING THREE 36 BY 54-INCH WASHERS AND A 26-INCH EXTRACTOR

laundry. One of these groups takes care of the average amount of work, while all three are in use on Mondays and Tuesdays or whenever work demands.

Another arrangement which can be used at times in the washing division, is to install a motor with two pulleys, one of which drives such machines as are in ordinary use, while the other is idle except on rush days. Such an arrangement should, of course, be laid out to give an average minimum load on the motor of at least 50 percent of its full rating.

It will be noted that the grouping of machines in the washing

division makes possible the use of the momentary overload capacity of the larger motor to start the extractor. The ordinary two-hour overload capacity of the motor may also be counted upon at times to run the extractor for the twenty to thirty minutes necessary for each charge of clothes.

The application of motors to the operation of drying is generally a simple one, as the dryers are usually self-contained and all that is required is to apply the proper size motor to the driving shaft. In a well arranged laundry the starching and starch extracting

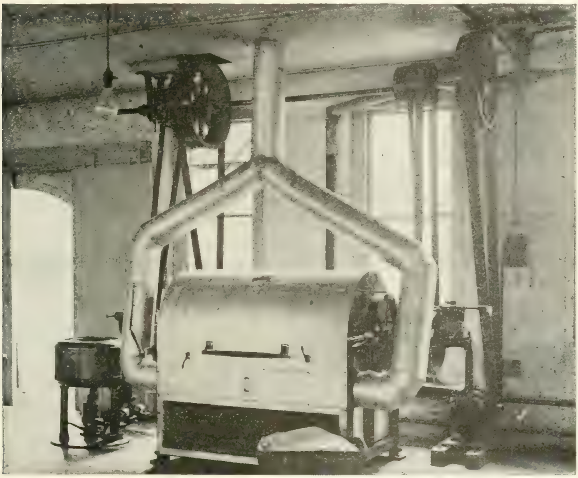


FIG. 3—DRY ROOM TUMBLING MACHINE AND STARCH EXTRACTOR, DRIVEN BY A THREE HORSE-POWER MOTOR

machines are driven in connection with the dryers, as these operations are carried on together and at times are continuous. A dry room tumbling machine and a 24-inch starch extractor, driven in a group by a three horse-power 1 120 r.p.m. motor is shown in Fig. 3.

The ironing division of the work ordinarily presents the greatest complications on account of the numerous machines used. Here the use of individual drive may work out well. The large mangles for the flat work frequently must be run overtime and must be operated at various speeds, so that the expense of an individual

drive is justified. A speed adjustment of *2* to *1* will generally take care of requirements in this respect and can easily be secured with either alternating or direct-current motors. When a system of cone pulleys is already installed to give various speeds, a constant speed motor can sometimes be used and the initial cost of the installation materially reduced. The collar and cuff mangle can usually be driven by a small constant speed motor and here again individual drive is advisable to make the operation of this machine independent of the other apparatus. The shirt ironing machines which, as re-

FIG. 4—IRONING MACHINES WITH INDIVIDUAL DRIVE

ferred to above, must be operated together, can be conveniently driven in a group by one motor as illustrated in Fig. 1.

An individual drive in the ironing division is particularly desirable in order to eliminate overhead belting and thus secure clean and light conditions. Fig. 4 indicates what good results can be had by such a layout. In this division overhead belts may be eliminated at times on the group drives, by hanging shafting beneath the floor and driving up to the machines in the group. Overhead group

drive may, however, be required, and the mangles can, of course, be so driven. A three horse-power, 1 120 r.p.m. motor, driving a group consisting of 100-inch and 66-inch mangles and a steam collar mangle, is shown in Fig. 5.

The application of motors to the other apparatus about the laundry plant does not present any difficulties, with the possible exception of the necessity of reducing from high motor speeds to the low speeds of driven shafting. Gearing is objectionable on account of the noise and wear. At times grooved pulleys and round belts may be used very satisfactorily. Such an installation is illustrated in Fig. 6, which shows a one-half horse-power, 1 700 r.p.m. motor

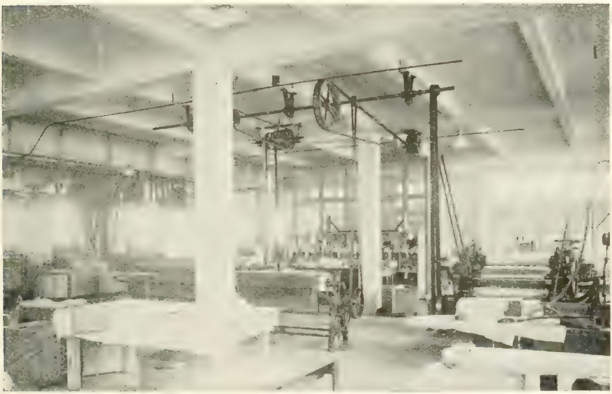


FIG. 5—THREE HORSE-POWER MOTOR DRIVING 100-INCH AND 66-INCH MANGLES, AND A STEAM COLLAR MANGLE

driving by means of four round belts a 112 r.p.m. pulley on the agitator in the chemical tank of a water softening outfit.

Some laundry operators seem to hold the opinion that alternating current is not satisfactory for driving their apparatus. This is probably due to the fact that in some of the first plants that were equipped with motor drive, small direct-current generators were belted to the engines and direct current was used throughout. In such cases, no doubt, the direct-current system applies very well, because of the small capacity of the generating and motor equipment required. Squirrel-cage motors are in general

superior to direct-current motors for laundry work, in that they have no commutator or sliding contacts, and alternating-current service should be selected whenever possible. This is particularly true in the washing department where with direct current it is at times necessary to use an entirely enclosed motor on account of the moisture.

Laundry operators are at times slow to accept suggestions or recommendations from the representatives of central stations or motor manufacturers, feeling that they can look only to the manu-

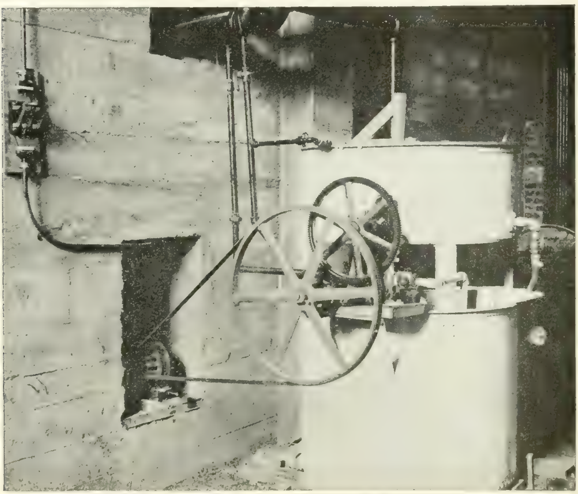


FIG. 6—CHEMICAL TANK OF WATER SOFTENING OUTFIT, DRIVEN BY A ONE-HALF HORSE-POWER MOTOR WITH GROOVED PULLEY AND ROUND BELTS

facturers of their laundry machines for information as to size of the motors and layout of their plants. This is probably a natural feeling, inasmuch as the development of the laundry business has depended to a large extent upon the designing of the machinery to carry on the processes, and the machinery manufacturers are the pioneers in this field. Whenever the power solicitor finds this feeling, it is necessary to use special effort to demonstrate by references that the driving of the plant with motors is a problem by itself, and

that this problem can be solved best by the power expert who is on the ground and can look the plant over with respect to layout, arrangement of shafting, grouping of machines, etc. The power expert on the ground can also install temporary motors, if advisable, and make tests to determine the exact size of machine required for any particular drive, and thus the proper size motors can be secured, which is not always the case if the installation is made on the basis of general recommendations.

The chief point to be settled between the laundry man contemplating the installation of motors on central station power and the power solicitor will no doubt be the cost of the power. The laundry man is apt to believe that inasmuch as he must have steam for the laundry work, he may as well run the steam through an engine, thus "getting his power for nothing," and use the exhaust throughout the plant. This question of cost of power is such a wide and indefinite one that it cannot be discussed here except to mention that experience shows that many laundries are now purchasing power and find it most satisfactory. One proprietor who recently installed an alternating-current motor equipment after several years experience with the old system of drives, states that he "would not take an engine again if someone would offer to give it to him."

MOTOR DRIVE IN POTTERY AND TILE MANUFACTURIES

A. E. RICKARDS

THE manufacturers of pottery and enameled decorative floor and mantel tile have, as a class, been slow to look into the question of motor drive for their apparatus, especially in connection with purchased power, as the use of exhaust steam in the dry rooms has been considered as outweighing all other considerations. The nature of the work is such, however, that individual motor drive offers many advantages, and such installations as have been made show decided savings, accompanied by an increase in output. The use of belts and line shafting in factories of this type is especially disadvantageous, on account of the fine clay powder which fills the air and collects on belts and pulleys, works into the hanger bearings, etc., producing excessive belt slippage and large friction losses. Considerable difficulty is quite generally experienced in keeping the machinery at proper speed on full load, and the output of the plant is in many installations limited on account of the belt slippages. The introduction of individual motor drive will, in such cases, increase the output of the factory by ten to thirty percent without any other increase in factory equipment, extra floor space or increased labor.

In making tile, the dry process is used. That is, the material when pressed into the moulds is a fine dry powder. In the wet process, used in the manufacture of pottery, the material is in the form of a wet clay when moulded into its final shape. The initial preparation of the raw material, however, is identical in the two processes.

The material from which both tile and pottery are made consists of a mixture of flint, feldspar and clay. A charge of these substances, weighing about 4 000 pounds, is thoroughly mixed with sufficient water to give it the consistency of heavy cream in a large tank called a "blunger mill." The mixing is done by means of paddles revolving on a vertical shaft, which is direct-connected to a horizontal driving shaft by means of a bevel gear. The charge is stirred from four to six hours until a uniform consistency is secured. The "slip," as the mixture of clay and water is called, then goes to a sifter, where a copper wire screen with a mesh of 100 per inch, oscillating at about 400 times per minute, removes all lumps,

pebbles or foreign matter, but allows the slip to pass into a storage cistern called an "agitator," where it is kept until ready for use, usually only a few hours. As the flint and feldspar are insoluble, and would soon settle to the bottom if left standing, a paddle is rotated in the cistern at a rate sufficient to keep the mixture in constant motion.

The blungers, sifters and agitators are mounted in close proximity to eliminate pumping, and are ordinarily driven by belts from a line shaft. These belts are very much in the way, and, when a heavy charge is put in the blungers, the slippage is quite large, caus-

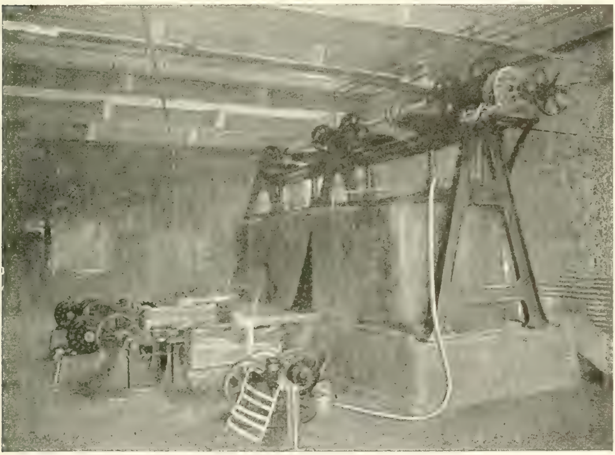


FIG. 1—TWO DOUBLE BLUNGERS DRIVEN BY A 10 HP, 1 120 R.P.M. INDUCTION MOTOR

ing a decided reduction in the capacity of the mills. Direct motor drive, such as shown in Figs. 1, 2 and 3, has increased the output by 15 percent over that secured by the use of belts from the same machines in the plant illustrated.

From the agitator, the slip is pumped into the slip press, a rack containing a number of iron plates, between which are canvas sacks. The pressure from the pumps is sufficient to press the greater part of the water out through the canvas, and leave layers of the clay deposited between the plates. These pumps which lift the slip to

the presses operate against very little pressure as they start pumping into the empty presses. As the press gradually fills, the pressure increases until by the time its capacity is reached the pumps are operating at a pressure of from 100 to 110 lbs. With belt drive, unless very large heavy belts are used at excessive tension, the slippage increases very rapidly with the pressure, increasing the amount of power and the time required to pump a charge. With the pumps shown in Fig. 4 driven by belts, 45 to 50 minutes were required to pump a charge of one ton. With the motor geared to the pumps, the same work is done in 15 minutes.

The clay at this stage is moist and sticky, and is, by reason of

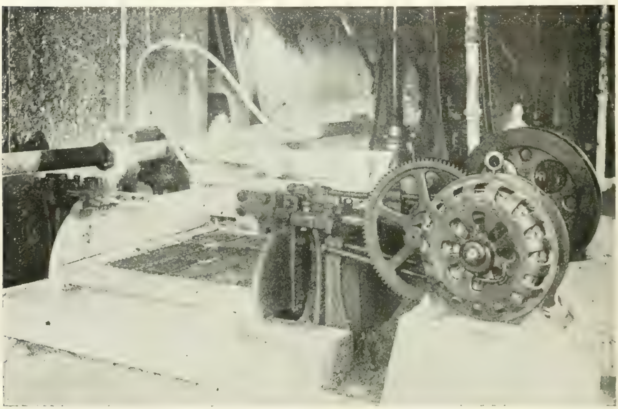


FIG. 2—SIFTER, DRIVEN BY A 3 HP, 1 120 R.P.M. INDUCTION MOTOR

the treatment it has passed through, uniform in composition and free from lumps, pebbles or foreign material.

The processes in the manufacture of tile and pottery are identical until the wet clay is removed from the slip presses. From this stage the processes are different. To secure the dry material for the making of tile, the wet clay from the slip presses is placed on racks in a heated drying room, where all the moisture is evaporated. The hard clay is then passed through a crusher, which breaks it up into small pieces, after which it is ground into a fine powder in the dust mills. These mills, Fig. 5, are usually 36 to 48 inches in diameter, and are provided with paddles or fans, which revolve

at about 1 200 r.p.m. inside a cast iron case. The high speed and the small clearance between the paddles and the housing works the clay into a very fine dust.

On account of the high speed, necessitating large pulleys on the driving shaft and small ones on the mills, and on account of the dust which continually accumulates on the belts, forming a glazed surface, the driving of a dust mill by means of a belt offers many annoying features. The heavy tension necessary to reduce slippage produces large friction losses, while considerable trouble is frequently experienced from belts breaking, or jumping off the pulleys.

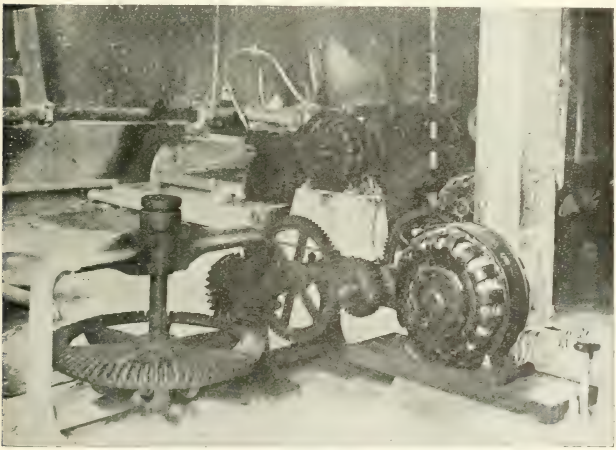


FIG 3—AGITATOR DRIVEN BY A 3 HP. 850 R.P.M. INDUCTION MOTOR

With line shaft drive it is necessary, in such cases, to slow down or stop the engines to replace one belt, thus delaying the work in the entire plant. Even when no such trouble is experienced the slippage is usually large enough to appreciably decrease the output. Thus, the dust mill shown in Fig. 5 ground only four tons of clay per hour when driven by belt without interruptions, while when direct-connected to a motor, the output was increased to five tons per hour, and, owing to the more uniform speed, a finer quality of dust is secured than was possible before.

The fine, dry powder produced by the dust mills is moulded

into forms by hand presses, after which it is ready for the initial firing.

Pottery ware, as previously stated, is moulded from the moist clay. The clay from the slip presses is of the right consistency, but is liable to have the moisture unevenly distributed throughout the cakes. These are, therefore, passed through a pug mill, to insure uniformity of the materials. This mill is a round tank, open at the top and having a vertical shaft with a number of paddles, which

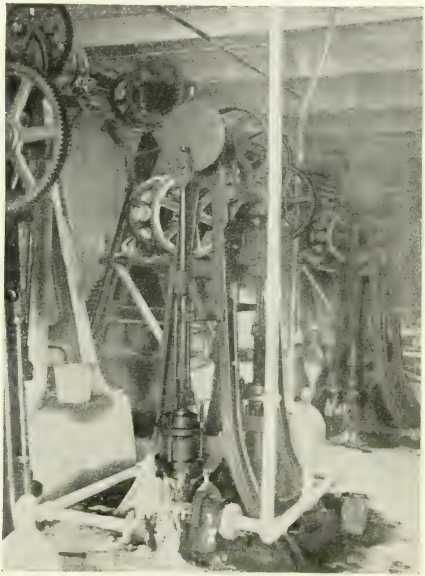


FIG. 4—SLIP PUMPS, DRIVEN BY A 5 HP, 1 120 R.P.M. INDUCTION MOTOR

when revolving mix the clay and at the same time push it to the end of the tank where it is pressed through a die about eight inches in diameter located near the base. The clay from the pug mills is then moulded into the finished ware on machines called "jiggers" or "jollies." This green ware is soft and full of moisture and is accordingly thoroughly dried in a heated drying room called the "green" room.

The firing of the ware is practically the same for both tile and pottery work. The dry ware is exceedingly brittle and easily damaged, and is protected from injury in the kilns by being enclosed in fireproof clay receptacles, called "sagars." The temperature depends on the quality and thickness of the material to be burned. In order to determine the temperature of the ware during the firing, several pointed cones, built up of flint and clay, are placed in the kiln where they can be observed through a peep-hole. The cones are numbered, according to the amount of heat they will stand, the melting point being determined by the percentage of flint. When the sharp points of the cones bend over from the heat, the potter knows by experience what temperature he is getting.

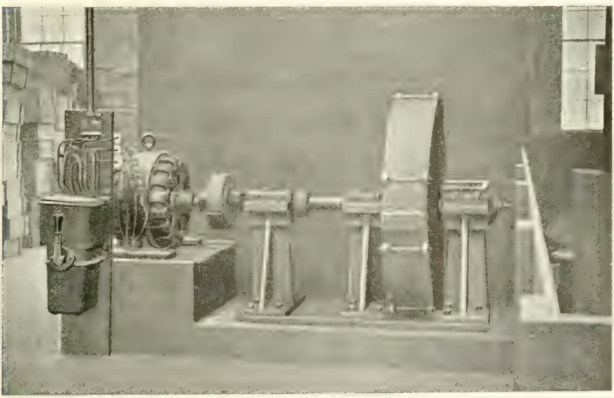


FIG. 5—DUST MILL, DRIVEN BY A 20 HP, 1 120 R.P.M. INDUCTION MOTOR

After the initial firing, the ware is decorated, refired and glazed. The raw material from which the glazing is made resembles glass very closely. It is ground up in the glaze mills, Fig. 6, which are similar to the tube mills used in cement works and mines. They consist of steel cylinders lined with porcelain brick and containing several hundred pounds of small cobble stones, the "frit," as it is called, being ground up between the sides of the rotating cylinder and the pebbles. When ground into a fine dust, the frit is mixed with water and is ready for use. Pottery ware is dipped entirely into the glazing. Tile is glazed on one side only. The ware is again fired, and is then ready for the market.

Both tile and pottery ware are placed in sagars for each firing. This constant handling breaks a large number of the sagars so that it is always necessary to have a sagar department in order to keep up the stock. The broken sagars are crushed in a "grogg" pan of the type shown in Fig. 7. This consists of a pan five to seven feet in diameter, the bottom of which is made of cast iron plates full of fine slots. Suspended in the pan are two heavy steel rolls, each weighing from 600 to 700 pounds. Material thrown into the revolving pan is crushed under the rolls and sifted through the slots in the bottom of the pan into a bin. This material, known as "grogg," is mixed with clay, passed through a pug mill and formed into new sagars, which are fired and are then ready for use.

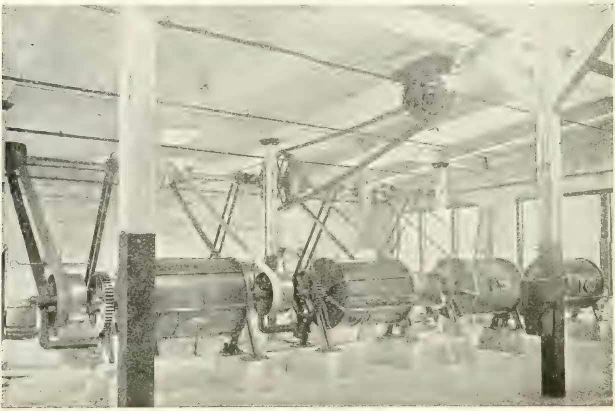


FIG. 6—GLAZE DEPARTMENT, DRIVEN BY A 15 HP, 690 R.P.M. INDUCTION MOTOR

In the sagar department there is usually a "wad" mill, similar in construction to a pug mill, except for the die at the bottom of the mill. In the wad mill this die has a large number of holes through which the material is pressed, forming strings of clay, which are placed between the sagars when they are stacked up in the kiln, to keep them from burning together.

The wad mill, grogg pan, sagar pug mill and sagar press can all be driven with advantage by individual motors, with a considerable saving of both power and labor. In fact, one of the notable features of the change from belt to motor drive is the increased output per man which is thereby effected. On the other hand,

the glaze mills are usually driven in a group, as a nearly uniform load can thus be secured on the motor, and the friction losses are usually not excessive.

Several of the illustrations in the present article show apparatus at the plant of the Mosaic Tile Company, at Zanesville, Ohio. This firm formerly had an 80 horse-power Corliss engine driving a long line shaft in their preparation room, operating the blunger mills, sifters, agitators, slip pumps, crushers, dust mills, and dust mill conveyors and sifters. They also had an 80 horse-power tandem gas engine driving a generator which furnished power for motors operating group drives in the machine shop, ball mills, sagar and glaze departments, and also the necessary current for their lighting system. With this equipment, their power costs per month were as follows:—

Engineer's Salary	$65.00
Coal and gas	180.00
Up-keep of belts	25.00
Loss due to shut-downs on account of belt troubles	25.00
Oil and waste	20.00
Gas engineer	6.25
Gas engine maintenance and repair	25.00
Five percent loss in time due to gas engine shut-downs	60.00
Incidentals	8.25
Total	$414.50

The belt troubles mentioned were largely at the dust mills where considerable difficulty was experienced on account of belts breaking and also jumping off due to the high speed and the necessity of using such large pulleys on the line shaft and small ones on the mills. Every time a belt came off it was necessary, in order to replace it, to slow down the engine, thus delaying the work in the entire plant. This occurred several times a week. The item, gas engineer, covers the time of a machinist who devoted only a part of his time to this work. The steam engineer, in addition to the care of the steam engine, also took care of all belt repairs and the oiling and care of the shafting.

The demand for power at this plant finally became greater than their capacity, and they disposed of their engine equipment and installed motors, buying power from the Ohio Electric Railway Company, of Zanesville, Ohio. The belts were eliminated entirely in the preparation room, and, in fact, there are but six driving belts left throughout the entire factory, with 35 motors installed.

As a result of the change, the capacity of the entire plant was increased fully 20 percent over their old method, while at the same time the cost of power, including repairs, does not exceed $150.00

per month. This affords a clear saving of over $250.00 per month in spite of the increased output. In addition an appreciable saving in labor was effected. In the sagar department, for instance, eight men were formerly required to keep up the stock of 85 000 to 90 000 sagars required. Motors geared direct to the grogg pan, pug mill and sagar press have so increased their capacity that six men are now able to keep up this stock.

One serious difficulty confronting the management at the time of the proposed change was the heating of the dry room, which had been heated by the exhaust steam from the engines. At present they are utilizing the waste heat from the kilns. When a kiln is drawn, after the material has been burned, the fire is shut off and

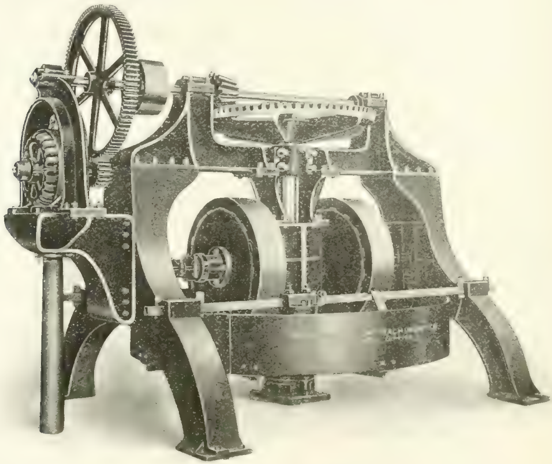


FIG. 7—GROGG PAN, DRIVEN BY AN INDUCTION MOTOR

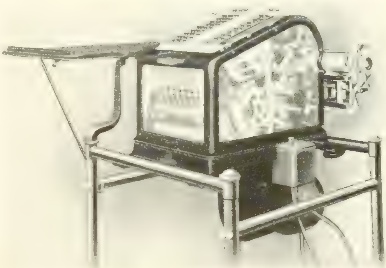
the kiln and its contents allowed to cool slowly. This heat is now drawn by a fan and blown through the dry rooms, and, as there are always several kilns being drawn at one time, they have more than enough heat.

Tests have been made on several tile factories where individual motors have been installed and they show an average of 28.2 kw-hr consumed per month per horse-power installed. On the basis of a nine-hour day the load factor will run from 15 to 20 percent, this latter figure being quite safe to use in estimating the cost of power for such installations.

SMALL MOTOR APPLICATIONS

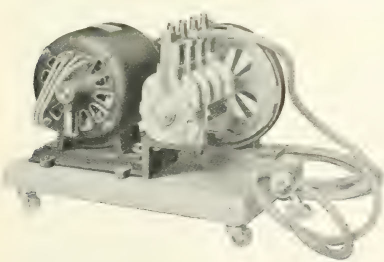
BERNARD LESTER

THE remarkable increase in the use of small alternating and direct-current motors for the operation of numerous useful devices employed in shops, offices and homes, has been due largely to the extension of electrical circuits by central station companies—thus making power available in all business, residence and often country districts—and the perfection of the small, single-phase induction motor. A simple and durable motor is, of course, as necessary as cheap and reliable power, and though small motors, both for alternating and direct-current circuits have been available for a number of years, the single-phase induction motor of simple construction, light weight and automatic starting characteristics has been developed more recently.



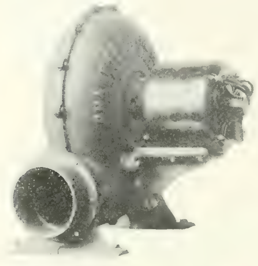
MOTOR-DRIVEN ADDING MACHINE

Since this field of motor service is, comparatively speaking, of recent origin, a number of problems have developed in connection with the application of small motors for these machines that are new and do not parallel the problems encountered when larger motors are applied for industrial service. Furthermore, since hundreds and even thousands of motors of one type and size are often applied to a particular type and size of driven machine, a very careful analysis must be made in order to secure the correct drive. A motor of insufficient margin of safety with regard to the essential electrical and mechanical characteristics for the operation of a particular machine,



MOTOR-DRIVEN TIRE PUMP

is very likely to give trouble and fail when the operating conditions cease to be ideal, involving a large amount of expense and trouble, particularly when it is considered that these small motor-driven devices are scattered all over the country. On the contrary, an abnormal margin of safety in these characteristics must be avoided, in the interest of economy. The question of the selection of the correct size of motor is largely, therefore, a consideration of limiting conditions of operation.



MOTOR-DRIVEN FORGE BLOWER

The user of the small motor-driven device is frequently unfamiliar with the details of construction of the motor and the care that should be given it. While in the case of the larger applications in factories, the motors are usually inspected and cared for by expert attendants, this is not true of the small motor-driven machines. When difficulties do occur with small motors they are generally found to be caused by conditions imposed upon the motor which any electrician would know to be wrong, but which are not so recognized by the ordinary householder.

APPLICATION OF FORGE BLOWER

Small motor applications fall into four fairly well defined classes, depending upon the length of the operating period and the variations of load while in service, viz.,

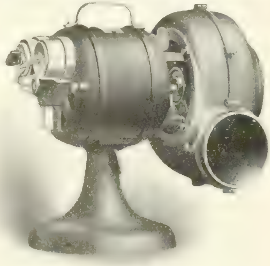
Motors operating continuously, with approximately constant load; for example, ventilating fans and forge blowers.

Motors operating continuously, with varying load; for example, sign flashers and adding machines.

Motors operating intermittently, with constant load; for example, coffee grinders and most automatic piano players.

Motors operating intermittently, with varying load; for example, household washing machines, ice cream freezers for household use and portable vacuum cleaners of certain types.

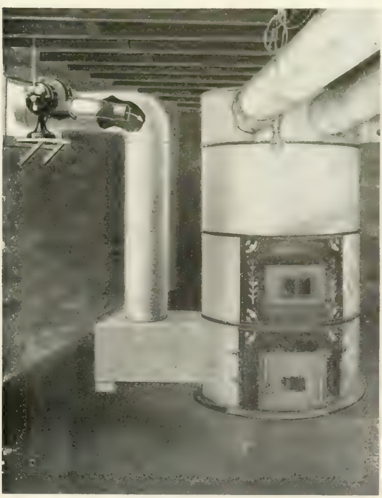
In addition to the above a further classification should be made according to the nature of the driven device, which involves the relation between torque required to start and accelerate the device and the torque required to run it.



MOTOR-DRIVEN VENTILATING BLOWER

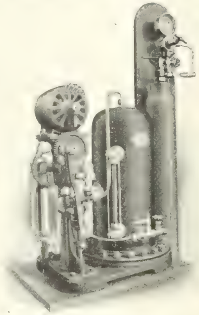
Before considering a selection of motors of proper characteristics for the various machines coming under the classifications just given, it will be best to analyze briefly the general features of all small motors which are of particular importance in the field of small motor applications.

It is obvious that motors for this general class of service must be of a neat and attractive appearance, since they are to be used in the home, the office or the shop and in connection with or as a part of machines highly finished and pleasing to the eye. Lightness of weight is also of considerable importance, for many small motor-driven machines are of a portable or semi-probable character. Maximum output in minimum space is another desirable feature; often the motor is an integral part of the portable driven machine. Cleanliness and freedom from the danger of throwing oil or grease are features absolutely necessary on account of the surroundings under which these motors are used. Care must be taken also that no uninsulated conductors or terminals are ex-



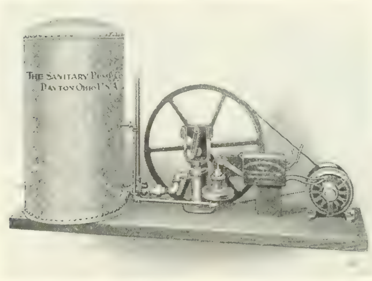
VENTILATING BLOWER ATTACHED TO FURNACE

posed, a shock from which might endanger or at least badly frighten the operator of the machine. Quiet operation is always desirable, and where motors are for use with musical or talking instruments, it is absolutely essential. Automatic starting of the motor, a feature that could not be accomplished in the earlier types of small single-phase motors, is important, as most of the machines driven by small motors must be connected directly to the electric light sockets and operated by means of a snap switch.

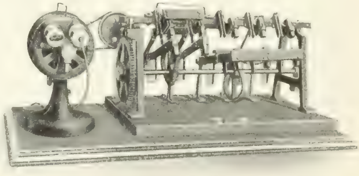


ELECTRIC CARBONATOR

Those electrical characteristics which must be taken into consideration in the application of these motors are: horse-power, speed at rated load, speed regulation, maximum or pull-out torque, starting torque, efficiency and heating under various conditions of load. Upon split-phase induction motors so commonly used on alternating - current circuits, questions of power-factor and starting current are also to be considered. In most applications of this sort the load is of a varying nature, often consisting of heavy peak loads for short intervals, so that the matter of maximum or pull-out torque, and also starting torque, is of primary importance. Particularly close speed regulation is not of importance in most small motor applications.



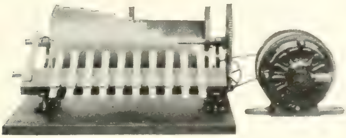
SMALL WATER PUMP FOR DOMESTIC USE



MOTOR-DRIVEN ELECTRIC FLASHER

The shunt - wound direct-current motor, or one lightly compounded, possesses those

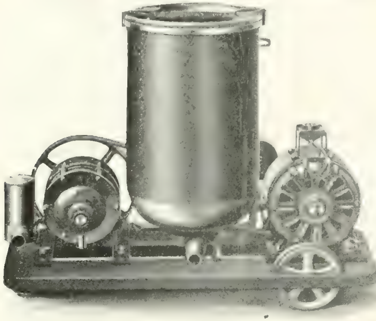
characteristics particularly suited for the average small motor application, having usually a starting and maximum torque of from four to five times the full-load torque. The limiting features of a direct-current motor are, therefore, not starting torque or maximum torque, but temperature, so that it is safe in general to select the proper size of shunt or compound-wound direct-current motor with reference to the horse-power developed continuously at a specified temperature rating. It sometimes occurs, however, that the peak loads imposed upon a motor are of such duration as to tax its capacity for heat absorption, so that an analysis of heating characteristics at severe overloads becomes necessary in order to specify the proper size of motor for a given cycle of operations. As the tendency in the design of small motors is to reduce the size of motor for a specified output and thereby reduce its weight, its capacity for absorbing heat developed during periods of sudden overload may, in certain applications, become a limiting feature. During peak loads the commutating characteristics of a direct-current motor should also be carefully noted. If the sparking is not pronounced and the duration and frequency of the peak loads are not abnormal no ill effects need be looked for, as during periods of light load, with the increase in speed the commutator will naturally polish itself.



MOTOR-DRIVEN SIGN FLASHER

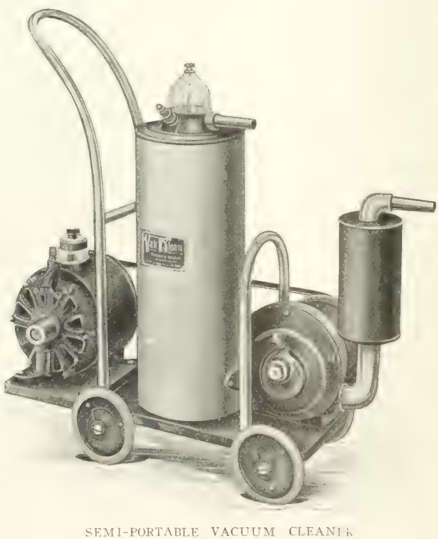
MOTOR-DRIVEN VACUUM CLEANER
Fan type.

From the electrical characteristics of small direct-current motors it will be seen that the problems in connection with their application are similar in many respects to those met with in the application of larger motors for industrial service. The speed-torque characteristics of the series wound motor make it readily applicable to most types of fans and blowers used with vacuum cleaners and in ventilation, where the fan is rigidly connected to the motor shaft.



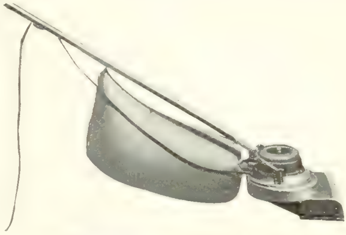
SEMI-PORTABLE VACUUM CLEANER
Rotary Pump Type.

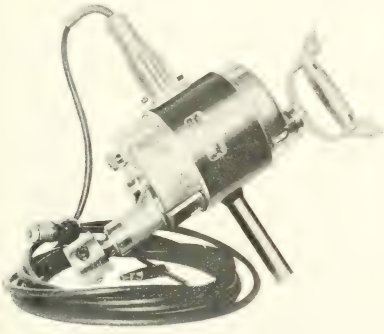
The inherent speed-torque characteristic of a split-phase induction motor differs from that of a shunt wound direct-current motor with which the public is perhaps more familiar, and presents limitations of a different nature. The synchronous speed of these motors is, of course, fixed by the frequency of the circuit and the number of poles for which the



SEMI-PORTABLE VACUUM CLEANER
Positive Rotary Pump Type.

motor is wound. It is becoming common practice to design direct-current motors with full-load speed approximately equal to the full-load speed of alternating-current motors for use on 60 cycle circuits, as most small motor-driven devices must be supplied with either alternating-current or direct-current motors, depending upon the local supply current. The inherent speed regulation of a motor of this type between no load and full load is slightly less than that of a direct-current shunt wound motor of equivalent rating and presents no drawbacks.

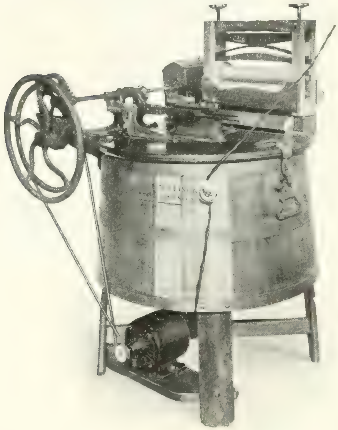

MOTOR DRIVEN SUCTION SWEEPER


PORTABLE ELECTRIC HAND DRILL

With the earlier forms of small split-phase induction motors, it was found difficult to obtain a sufficiently high starting torque for starting and accelerating the majority of small motor - driven devices, and the centrifugal clutch was employed in order to bring the value of torque at start to a point closely approaching the pull-out torque of the motor. The rotating element is so constructed that the spider supporting the secondary punchings, windings and clutch weights revolves freely upon the shaft to which the clutch bell is connected. Thus upon connecting the primary circuit to the line, the secondary

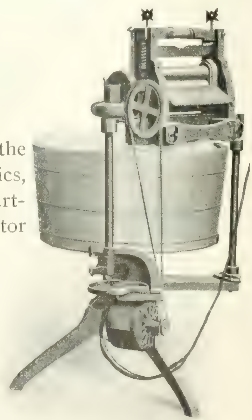

MOTOR-DRIVEN INK ERASER

comes up to a point somewhat below full-load speed before the clutch takes hold. At this point the torque exerted upon it has increased in value, so that the clutch takes hold when the torque is slightly below its maximum, or pull-out value. Due to improved design, and in the interest of simplicity, the use of the clutch has largely been eliminated, and it is possible to obtain split-phase motors for speeds and frequencies commonly met with, having a starting torque equal to that at full-load without the use of the centrifugal switch. The starting torque may even be increased beyond this limit at the sacrifice of other electrical characteristics, such as efficiency, power-factor and starting current. A split-phase induction motor of normal characteristics without clutch may be considered as one having a starting torque equal to full-load and a maximum pull-out torque of twice full-load torque.



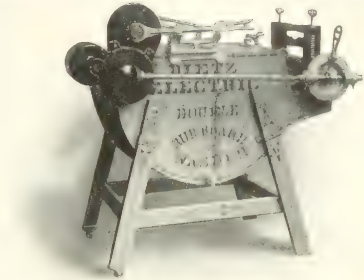
MOTOR-DRIVEN WASHING MACHINE AND WRINGER
Reversing Dolly Type.

Since many of the small motor applications involve the starting and accelerating of heavy loads, and the motors, when in operation, are subject to loads of varying torque often possessing sudden peaks, the two features of starting torque and maximum torque often become limiting factors in applying these motors. The purchaser is thus interested most in the starting and pull-out torque, and usually



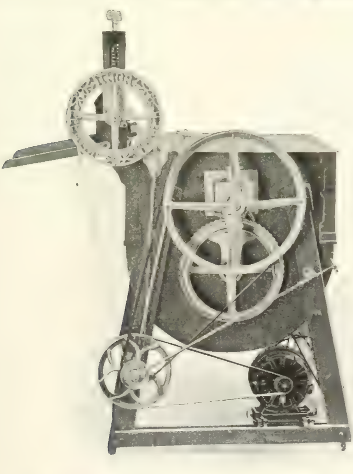
MOTOR-DRIVEN WASHING MACHINE AND WRINGER
Revolving Tub Type.

to a less degree in the heating characteristics of the motor, which will determine its ability to carry a specified load continuously. Thus it will be seen that the horse-power designation of the split-phase motor is not always a measure of its usefulness, and it will be quite possible to select a one-sixth horse-power motor which will be called on to develop less than its rated horse-power in driving, for example, a household washing machine, but would not possess a sufficiently high torque to start the machine or take care of the peak loads of the wringer. A high power-factor and low starting current are, of course, desirable features in small alternating-current motors, but the importance of these characteristics does not equal those already discussed.



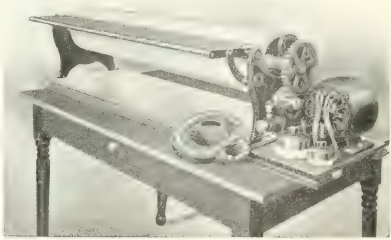
MOTOR-DRIVEN WASHING MACHINE AND WRINGER
Employing Double Rub Board.

The starting current of a single-phase motor is considerably in excess of the full-load current. Upon the smallest motors, since its absolute value is not great, this requires little consideration. As the size of the motor increases, however, to say one-quarter or one-third horse-power and larger, this feature is of greater importance, since the carrying capacity of the supply circuit must be considered. The starting torque of a single-phase induction motor varies approxi-



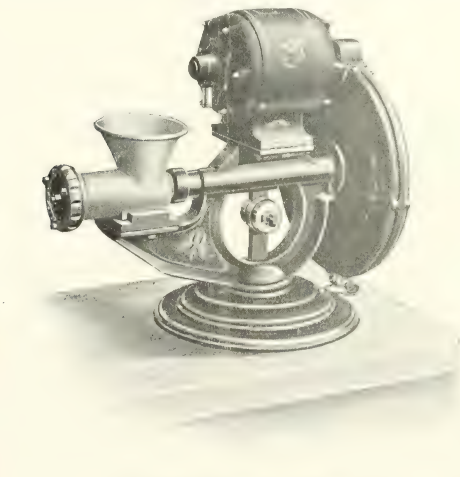
MOTOR-DRIVEN WASHING MACHINE AND WRINGER
Reversing Drum Type.

mately as the square of the voltage applied to it. Therefore it is important that the conductors be of sufficient size that the voltage applied to the terminals of the motor while starting does not fall materially below the rated voltage of the circuit and thus reduce the starting torque.



MOTOR-DRIVEN, GAS HEATED LAUNDRY MANGLE

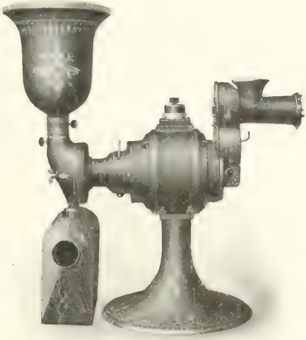
In addition to being desirable for obtaining a high starting torque where this cannot be obtained without its use, the centrifugal clutch decreases the effect of the current taken at starting upon the supply circuit, since the period during which the rotor is accelerating is greatly reduced. Furthermore, in certain types of motor-driven machines, where, through some accident, an abnormal load is suddenly placed upon the motor, the clutch will slip, thereby protecting the motor for a short period of time and giving the operator a chance to disconnect it from the circuit.



MOTOR-DRIVEN MEAT CHOPPER

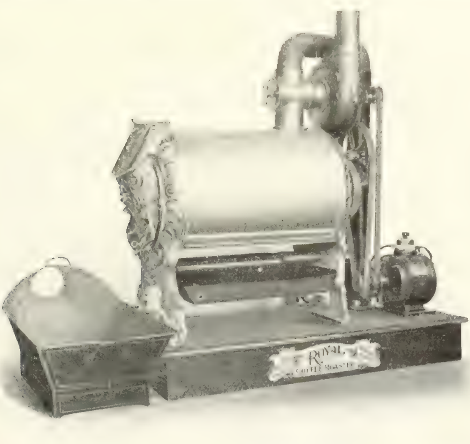
Since many small motor-driven machines are connected to the circuit and under actual service conditions for short intervals only, and are idle a greater part of the time, for the sake of economy the purchaser frequently desires to supply the smallest possible motor that will meet the ordinary service condi-

tions. This is not a wise plan to follow. Machines of this kind are often operated by inexperienced individuals, and may be accidentally



COMBINED COFFEE GRINDER AND MEAT CHOPPER

left running for an indefinite length of time, so that if a motor is selected which will not operate continuously under normal condi-



MOTOR-DRIVEN COFFEE ROASTER

tions of load at a safe temperature, trouble results. In the case of the motor-driven portable vacuum cleaner, though the individual

owners may not operate these for longer intervals than, say, half an hour at a time, they may be rented by a central power company to their patrons by the day. Under such conditions they are called on to operate almost continuously when in the home of the patron. Observations such as these indicate the advisability of adopting a maximum method of rating; that is, rating the motor when supplied for intermittent service, on a basis such that it will operate continuously at a safe temperature under the load ordinarily placed upon it.

In selecting a motor of proper characteristics for a driven machine where the particular application is to be repeated again and again, the following general points should be taken into consideration:

> Variation in the essential electrical and mechanical characteristics of duplicate motors, incident to their manufacture in quantities.
>
> Variation in the value of torque required to start and power to drive duplicate driven machines, incident to their manufacture in quantities.
>
> Variations in the characteristics of the circuit on which the motors are to operate, such as variations in voltage, frequency or both.

The points in question can be well illustrated with a household washing machine to which is to be applied a one-sixth horse-power split-phase motor. The average motor as manufactured may develop a starting torque of ten ounces, but, through variations incident to manufacture, certain motors may have a starting torque as low as nine ounces, while in others it will be as high as eleven ounces. It is evident that the minimum figure must be considered in making the application. It is also evident that there will be some variations in the driven machines as manufactured in quantities, as to the load placed upon the motor when starting and running. Furthermore, it often occurs that at a certain position of the operating mechanism the torque required to start the machine is higher than at other points. The most severe conditions must always be taken into consideration.

Irregularities in the voltage of the supply circuits have been considered in the discussion of starting current. Conservative practice would lead to the specification that, considering the most adverse conditions of the motor and driven machine just outlined, the motor should start the driven machine on a voltage of from 80 to 85 percent of the normal voltage of the circuit on which it is to operate.

ESTIMATING ELECTRIC POWER COSTS

CHAS. R. RIKER

THE estimating of motor bills is a part of the daily work of the central station solicitor, the motor salesman and others. The accompanying chart has been prepared in an endeavor to eliminate most of the routine calculations from such an estimate.

The values used in the chart are based on the formula:—

$$\text{Bill} = \frac{\text{Rated Hp} \times \text{Max. Hrs. Use} \times 0.746 \times \text{Rate} \times \text{Load Factor}}{\text{Motor Efficiency}}$$

For convenience in determining the motor load factor, a maximum of 240 hours use of the connected load per month has been chosen as most generally applicable. This corresponds to the 55.5 hour week (10 hrs. per day, Saturday afternoon off) which is standard in many industries and is the nearest even number to the 54 hour week, which is standard in many others. The load factor is, then, the ratio of the actual monthly consumption to the use of the entire connected load at its rated capacity for 240 hours per month. It is the same as the average load when the latter is taken on a 240 hour per month basis. Load factors based on an 8 760 hour year or a 720 hour month can be multiplied by three and used on the chart without error. As an added convenience, values of hours use of full load per month and hours use of full load per day have been added and may be used interchangeably with the load factor. In using the values of hours use of full load per day, it should be remembered that these values are based on 24 full days per month, corresponding to 22 full days and 4 half days.

The respective motor efficiencies used in preparing the chart are shown by the curve, Fig. 1. They represent the average values of a number of standard commercial lines of motors, including squirrel-cage and wound-secondary polyphase motors and shunt and compound direct-current motors. They are chosen at three-quarters full load, in the belief that the average conditions of motor use will be more closely approximated at this fractional load than at full load. The values as shown will correspond very closely to the performance of any standard industrial motor.

Since the values given by the chart include the motor efficiencies, in calculating the cost of operation of a group of motors exact results will not be secured by figuring the bill for a motor whose size is equal to the aggregate of the smaller motors. More correct

results will be secured by calculating the cost of operating each motor separately at the appropriate load factor and adding the results. In case a number of motors are to be used at approximately equal load factors, or where a plant load factor is to be used, the bill for the average size motor in use should be calculated at the appropriate load factor and this result multiplied by the number of motors. However, the error introduced by basing the calculations on a larger size of motor will be small, and where approximate results only are desired, may be neglected.

Inasmuch as combinations of five variables, i. e., horse-power, load-factor, kilowatt-hour output, rate and cost are shown, it is necessary to use two quadrants of rectangular coördinates. Logarithmic coördinates are necessary in order to secure a sufficient range

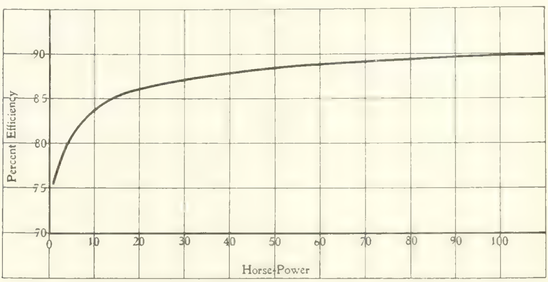


FIG. 1—AVERAGE EFFICIENCIES OF STANDARD LINES OF MOTORS AT THREE-QUARTERS LOAD

of values within reasonable space, with accurate readings at the lower values. This need not present any difficulty to those unacquainted with a logarithmic scale, as intermediate values may be interpolated in the usual manner without appreciable error.

The chart is read from a vertical line to a diagonal line and from the diagonal to a horizontal line in one quadrant, and along the horizontal to a diagonal line and from the diagonal to a vertical line in the other quadrant. All the operations are reversible, and each quadrant may be used separately for the values contained therein. The values can be read at all points with sufficient accuracy for commercial work, and a suitable range is included for all ordinary use. In case it is desired to secure some value which is off the scale, a load factor or a rate half that desired may be chosen and the result multiplied by two.

Example 1—What will be the consumption of a 40 hp motor running 60 hours per month at full load? What will be its cost at three cents per kw-hour?

Starting with 40 hp read up to the diagonal representing 60 hours per month. The horizontal value at the intersection shows a consumption of 2 000 kw-hours per month. Following this horizontal to the diagonal representing three cents per kw-hour, the vertical shows a cost of $60.00 per month.

Example 2—In a factory operated by a 30 hp motor, the monthly bill at five cents per kw-hour was $90.00. What was the load factor? What was the average load on the motor if it was run for 110 hours during the month?

Starting with $90.00 per month, read up to the diagonal representing five cents per kw-hour, then across to the vertical representing 30 hp. The diagonal shows a load factor of about 29 percent, corresponding to about 70 hours use of the motor at full load. The average load for 110 hours was then 63.5 percent of full load or 19 hp.

Example 3—In a factory operated by a steam engine, the indicator cards show an average load of 120 hp for 200 hours per month, and a maximum of 200 hp. The total cost for power is $300.00 per month. To what rate per indicated hp-hour is this equal? Assuming a mechanical efficiency for the engine of 75 percent, what rate per kw-hour will have to be given to allow a suitable motor to do the same work for the same total cost?

This load equals 24 000 hp-hours per month, indicated, which is equivalent to 18 000 kw-hours. Following the horizontal line representing 18 000 kw-hours to the vertical line representing $300.00 per month, the diagonal shows a value of 1.25 cents per indicated hp-hour or, at 75 percent efficiency, 1.67 cents per brake hp-hour.

To carry the same maximum load, a motor of $200 \times 0.75 = 150$ hp will have to be chosen. The output of this motor will equal the output of the engine, which at 75 percent efficiency equals 18 000 hp-hours per month. This corresponds to $18\,000 \div 150 = 120$ hours use of full load per month or a 50 percent load factor. Starting with 150 hp read up to the diagonal representing 120 hours per month and across to the vertical representing $300.00 per month. The diagonal shows a rate of about two cents per kw-hour, i. e., an electric motor operated on a two cent rate will cost about the same as the engine.

Example 4—With a rate of $2.00 per month per horse-power maximum demand, plus three cents per kw-hour for current consumed, what will be the bill of a shop operated by a 30 hp motor assuming a maximum demand of 60 percent of the connected load and a load factor of 40 percent? What is the equivalent straight rate?

Starting at the 30 hp line, read up to 40 percent load factor, across

to the three cent rate and down to $72.00 current charge. Add to this $30 \times 2 \times 0.60 =$ $36.00 and the resultant bill is $108.00.

Reading up the 30 hp line to the 40 percent diagonal and across to the $108.00 vertical, shows that the equivalent straight rate is about 4.5 cents per kw-hour.

Example 5—In a factory driven by two 20 hp motors, the rate for power is ten cents per kw-hour for the first 30 hours use of the maximum demand, five cents per kw-hour for the second 30 hours use of the maximum demand and two cents per kw-hour for all power used in excess of this amount. The bill, figured on a maximum demand of 60 percent of the connected load is $150.00. What is the load factor? What is the equivalent straight rate?

Reading from the chart:—

30 hours use of 24 hp at 10 cents=	$62.00
30 hours use of 24 hp at 5 cents=	31.00
Total for first 60 hours use=	$93.00

It is evident that $150.00—$93.00=$57.00 was based on the two-cent rate. The chart shows this to be equivalent to 135 hours use of the maximum demand. Then $135 + 30 + 30 = 195$ hours total use of the maximum demand, which is the equivalent of $195 \times 0.60 = 117$ hours use of the connected load. This corresponds to a little less than a 49 percent load factor. Reading from 40 hp to 117 hours use, to $150.00 per month, the chart shows that the equivalent straight rate is a little less than four cents per kw-hour.

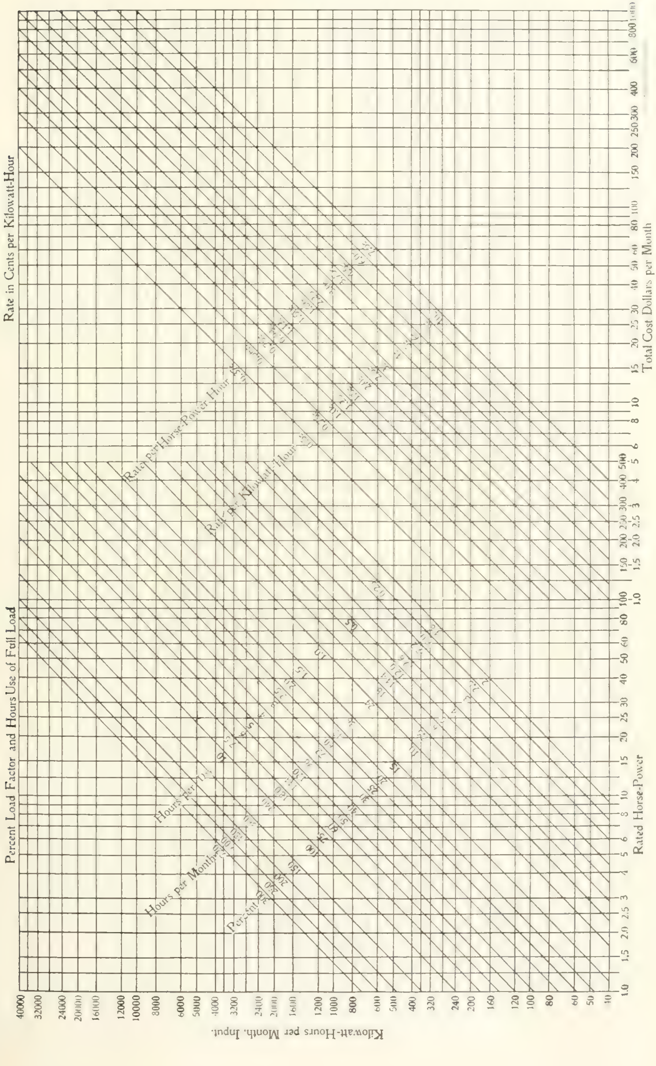
Example 6—A 15 hp motor driving a brine machine in a refrigerating establishment runs 24 hours per day seven days in the week. At a 1.5 cent rate the bill amounts to $95.00 per month. What is the average load on the motor?

Starting at $95.00 per month, read up to the 1.5 cent rate across to 720 hours per month and down to approximately 10 hp, the average load on the motor.

Example 7—A factory is operated by three 5 hp, four 10 hp and three 15 hp motors. What will be the bill at three cents per kw-hour at a 15 percent load factor?

As the efficiencies of these motors will be different from the efficiency of one motor equal in capacity to their sum, it is advisable to calculate the bill from the average size motor. This total load amounts to 100 hp and the average size of the motor is therefore 10 hp. Starting at 10 hp, reading to 15 percent load factor, across to a three-cent rate and down, the bill is seen to be $9.60 per motor or a total of $96.00.

If the bill is calculated for a 100 hp motor at the same rate and load factor, the result is a little less than $90.00 per month. The difference is due to the different efficiencies of the 10 hp and 100 hp motors.


Rate in Cents per Kilowatt-Hour
Percent Load Factor and Hours Use of Full Load
Total Cost Dollars per Month
Rated Horse-Power
Kilowatt-Hours per Month, Input.
Rate per Horse-Power Hour
Rate per Kilowatt-Hour
Hours per Day
Hours per Month
Percent

In estimating motor bills, some reliable basis for determining the load factor is absolutely necessary. When used without a knowledge of the local conditions at the plants from which the data is obtained, tables of load factors are apt to be misleading. Too many such tables are based on only one or two installations of a particular kind, all located in a comparatively restricted territory, and hence cannot be said to represent even average conditions.

The central station representative has, however, or can secure from his company's records, from the records of associate companies, or from the technical press and various motor manufacturers, all the information necessary to form a card index system of load factors and correlative data which will be of great value in forming estimates. Each card should contain information relative to a single plant. This should include, in addition to the location and electrical characteristics of the plant, full data as to the character of the product, capacity of the equipment, average output, number of machines, their arrangement and method of drive, number of men employed, hours of operation per month, power consumed per month and, when possible, per unit output, maximum demand, average load per horse-power connected and load factor. The card should be filed according to industries, similar plants being grouped together.

Such a reference index will allow of ready and accurate comparison between any given plant and all others of which complete data can be obtained, and will at the same time avoid indiscriminate comparisons between plants operating under widely different conditions. Its value will, of course, vary with the number of plants outlined, and becomes greater when several operating companies open their records to each other.

In analyzing a proposition, too great dependence should not be placed upon comparisons, however accurately made. A careful estimate of the probable load on each motor, together with the probable time of operation should always be drawn up as a check. Such an estimate requires considerable experience and sound engineering judgment. When made, however, in connection with a well kept card index system of load factors and tempered with a goodly amount of common sense, a close approximation to the actual cost of operation should result.

WINDING OF DYNAMO-ELECTRIC MACHINES—IX

INSULATING MATERIALS

R. H. ARNOLD

THE efficient design of electrical apparatus requires that the maximum amount of its weight and bulk shall be occupied by electrically and magnetically active material, and as little insulation must be used as is consistent with safety. Both iron and copper must be made to yield the maximum results, and the various parts of the apparatus must be kept electrically separate while mechanically bound rigidly together to overcome the effects of the centrifugal strains and the magnetic reactions which take place between the current carrying parts. The ideal insulation or separating agent must, therefore, have high dielectric strength and high resistance, and must be absolutely uniform in order that the factor of safety may be increased as far as practicable. It must be capable of withstanding high temperature without deterioration, i. e., it must not oxidize, it must not soften, it must not contain volatile matter. It must not be weakened by the electrostatic stresses to which it will be subjected, and must be moisture and oil proof, and sometimes acid proof. It must be tough, incompressible, and mechanically strong.

In addition to this the practical design of the apparatus from the commercial standpoint requires that the insulation be readily and quickly applied. This means that the material must in some cases be flexible, and in others must be easily machined or moulded. It must be readily procurable in the necessary quantities within reasonable time, without excessive cost.

Naturally such conflicting characteristics cannot be obtained in any one material. Many substances are softened by heat, while others are oxidized or rendered brittle, and a large number of those materials which have a high dielectric strength are either highly inflammable, or are hygroscopic and absorb moisture. Other materials, which have good electrical, temperature and moisture characteristics, are very difficult to put to practical use. The work of the insulating engineer is, therefore, so nicely to coördinate the characteristics of the materials available as to make them conform to the requirements of the apparatus under consideration. This is most commonly done by adding the characteristics of two or more different insulating materials in such a way as to give both the dielectric and the mechanical strength desired, while at the same time occupying as little valuable space as possible.

In order to suitably balance these various requirements, an exact knowledge of the materials commercially available is necessary. The first duty of the engineer is to study the characteristics of his materials, first, by themselves, and second, in conjunction with other materials.

It is probably unwise to attempt to give limits for the use of any insulating material, since the results desired, the conditions under which it is to be used, or the effect of other materials in combination may have a controlling influence on the service which may be obtained from any given material. One material may be eminently suited for use in one piece of apparatus, but totally unsuited for a similar piece of apparatus for different service; or unsuitable mechanical characteristics of the material may be entirely overcome by the judicious use of another material in combination with it.

What follows must therefore be taken as giving some of the applications, but with no attempt to give limitations of any single material or combinations of materials, and knowledge as to such limitations must be arrived at through experience and good judgment.

The insulating materials which have proven useful in the construction of electrical apparatus are relatively few in number, although they are found under a wide variety of names and conditions. Of these the various cloths and papers have by far the most general application. Of the cloths cotton is most widely used, on account of its lower cost. Silk and linen are both slightly superior in mechanical strength, but their superiority is not sufficiently great to overbalance their greater cost, except in some few cases, such as instrument coils, telephone receivers, etc., where the space requirements are rigid enough to warrant the extra cost.

COTTON

Cotton is valuable both on account of its excellent mechanical qualities, and on account of its high dielectric strength when impregnated with a suitable insulating varnish. It is flexible and tough and is easily applied either in the form of cloth or tape. On the other hand, in common with other organic fibers, cotton tends to grow brittle when subjected to continuous heating. Hence, when used where it is liable to be heated, cotton must be applied in such a way that it will not be subjected to vibration or mechanical strains which will break it. As long as the insulating sheet remains unbroken mechanically, it largely retains its original dielectric strength.

Cotton is used in the form of cloth, tape, and as thread closely wrapped around wires. As it is somewhat hygroscopic, it is seldom used around electrical apparatus without being treated with varnish or some impregnating compound to prevent the absorption of moisture. Often, however, especially in the case of tapes and cotton-covered wires, it is more convenient to make use of the untreated forms, and either varnish each layer as it is applied or impregnate the whole article after the winding is finished.

Whenever either cloth or tape is used primarily for its dielectric strength it is treated with an insulating compound before use, as much more uniform and reliable results can thus be secured. The cloth to be used for this purpose is led under a roll in the bottom of a vat of varnish and up through a heated tower where it is dried sufficiently to keep it from sticking to the roll over which it passes to return downward through the heater to be rolled up or to pass to a second vat if more than one coating is desired.

After treatment the cotton cloth has sufficient dielectric strength to withstand about 1 000 volts per mil thickness. It is non-hygroscopic and has very slight surface leakage. The surface may be quite hard and dry or may be soft and tacky, depending on the length of time the drying process is continued. As supplied to the trade, the surface is ordinarily coated with paraffine so that the sheets will not stick together, and to prevent the material from drying out. This form of insulation is flexible and quite tough and is widely used in the manufacture of electric machinery, for the insulation of generator and motor coils, etc. Since it is quite susceptible to abrasion or mechanical damage, it is seldom used without a protective covering of some sort, usually untreated cotton tape or friction tape, or some sort of heavy tough paper such as fish paper.

Another form of treating both cloths and tapes consists in the application of a flexible adhesive material called frictioning, from the manner of its application to the cloth. This is done by coating the cloth with soft rubber frictioning material and then thoroughly calendering it in by means of heavy rolls. The thickness of the finished product is determined by the thickness of the cloth and the amount of the rubber compound supplied.

Various weights and thicknesses of cotton cloth are used. Of these the more common are as follows:

Cambric is a light cotton cloth, about five mils thick, which has been given a heavy calendering. Its principal use is in the

form of treated cloth. Untreated it is used for sleeving on copper strap or wire, in coils which are to be impregnated with gum or varnish after winding.

Muslin is about eight mils thick, and is of a much softer weave than the cambric, i. e., the threads of the warp and the filler are not twisted so tightly.

Heavy Cotton, about 11 mils thick, is a strong, closely woven cloth used wherever considerable mechanical strength is required, as between layers of heavy wire coils where it is subjected to heavy pounding.

Drilling, about 17 mils thick, is used because of its great strength and resistance to mechanical injury wherever the heavy cotton is not sufficiently strong. It can be readily recognized by the herring bone weave, which causes small ridges to run diagonally across the sheet.

Duck, about 30 mils thick, is usually treated with linseed oil or varnish and is used as a protective covering over coil supports, between coil ends and over the ends of armatures, etc. It is also sometimes used between coil layers in order to lead the impregnating gums to the interior of the coil.

Cotton Tapes—Any of the materials mentioned may be slit into narrow widths and used as tape when great mechanical strength is not important. When strength is required, however, selvedge edge tapes are used. These tapes may be obtained in any thickness or width desired.

In some cases where it is necessary to tape an irregularly shaped coil, bias-cut tape will follow the surface more closely than ordinary tapes. This is obtained by cutting a sheet of cloth into strips on the bias. When this bias tape is desired in long lengths, the cloth before treatment is unrolled, cut and then sewed together in such a way that the threads do not run parallel with the edges. This roll of material is then treated and run through the slitter which cuts it into narrow widths.

Gauze tape is used as a temporary outside wrapper over coils which are to be impregnated, but where the presence of impregnating materials in varying thickness on the outside of the coils is undesirable. By the removal of the tape after the coil is cooled, all superfluous impregnating material is removed.

Cotton Sleeving, as its name implies, is a cotton braid used to slip over the coil leads as additional insulation. It is frequently used in various colors as an aid in winding armature coils.

PAPERS

The various papers belong in the same general class of insulating materials as the cloths. They are used for the same purposes and in much the same manner. Structurally they are composed of vegetable fiber, either linen, cotton, hemp, straw or wood, and hence are subject to the same limitations as to heating as the various cloths. They have, however, a distinct insulating value in themselves due to the absence of interstices between the fibers, and do not depend on varnish or gum treatment for their dielectric strength to so great an extent as do the cloths.

Papers are used for insulation in a wide variety of weights and structures, ranging from the thinnest of rice papers to the hard fiber board of an inch or more in thickness. The mechanical and electrical characteristics are dependent largely upon the material used and the processes employed in its manufacture. In general, the linen, cotton or hemp materials have the greatest mechanical strength, since this quality is to a large extent dependent on the length and the mechanical strength of the individual fibers composing the paper. Thus cement paper, which is made from old hemp ropes, is very strong and tough.

When used for their insulating qualities, papers are almost always treated with some form of oil or varnish. This treatment renders them non-hygroscopic and increases their dielectric strength very considerably. A good quality of paper, suitably varnished or impregnated, will withstand as high a voltage as the same thickness of treated cloth. All papers are, however, less flexible than cloth, and care must be taken to avoid creasing a paper which is to be used as insulation, since both its electrical and mechanical strengths are greatly lessened by a sharp bend.

Some of the papers which have been proven by experience to be valuable in insulation work are as follows:

Japanese Paper is an extremely thin white rice paper of considerable strength. Its name comes from the fact that it was originally imported from Japan. Its principal use from the insulation standpoint is as a support on which flexible mica may be built. Its thickness is approximately one mil.

Rope Paper, sometimes called cement paper, is made from hemp rope, and consequently has extra long fibers and great mechanical strength. The term "cement" comes from the fact that this paper was originally used in making sacks to hold Portland

cement. When suitably impregnated with an insulating varnish it is extensively used as an insulating material, both by itself and as a support for built-up mica, being made in thicknesses of from 13 to 30 mils. It has a dielectric strength after treatment of about 1 000 volts per mil in the weights commonly used.

Kraft Papers, made from chemical wood pulp, are coming into common use as wrapping paper. In insulation work they are used as substitutes for rope cement paper. They are brown in color and are all made by the same general process, but slight variations in the quality of the original wood fiber and in the process of digesting and beating produce important differences in the finished product, so that they do not all lend themselves to insulation work. The best of these papers come from Sweden and Germany.

Parchment was the term originally applied to sheepskin or goatskin which had been treated to make it suitable for use as a paper. This was a high grade material but was also very expensive. Early in the paper making industry it was discovered that by treating a fine cotton paper with acid, it could be converted into a strong waterproof sheet slightly resembling the treated sheepskin. It is this "vegetable parchment" which generally passes under the name of parchment paper. Its application in insulation work is limited to cases where its non-absorptive qualities are needed, such as preventing shellac or varnish from passing through a coil or piece of apparatus and cementing it to the support on which it is being built.

Fullerboard or pressboard, is a dense cardboard-like material ranging in thickness from seven to 125 mils. It is made up principally from rag stock and when it comes from the paper machine is a soft board resembling cheap cardboard or blotting paper in density. This is then passed through an extremely heavy calendering process and compressed down into the dense board which is known as fullerboard.

When suitably varnished, fullerboard has a dielectric strength of about 500 volts per mil in thicknesses under 25 mils, running down to as low as 200 volts per mil in the heavier sheets. The thinner sizes are used between turns and as cells or as filler in transformer and armature coils. The thicker sheets are used as washers in all classes of electrical apparatus.

Fish Paper is made from pure rag stock which is passed through a treating process much the same as the parchment paper,

coming out a hard, dense, fiber-like paper, possessing considerable mechanical strength. It must be very thoroughly washed after the treatment, the washing and curing process being extremely important from the insulation standpoint, since a small percentage of the chemicals used in the process, if allowed to remain in the sheet, will so rot it that it becomes very stiff and brittle, losing its mechanical strength and therefore its value as an insulation.

These papers, when properly cured, are not affected by heat to as large an extent as most of the other forms, and for this reason, and on account of their great mechanical strength, they are extensively used as protective cells in armature slots. Considerable care must be exercised in handling them, however, as these papers do not possess such great flexibility as the more common papers.

Hard Fiber is a very dense, hard, stiff material possessing great mechanical strength and considerable insulation strength. It is made from cotton stock which is passed through a treatment of zinc chloride. This causes a chemical change, producing a homogeneous mass. As in the fish paper the washing process here is very important, the zinc chloride producing disastrous results if not thoroughly removed. The washing and curing of some of the thicker sheets, say three-quarters to one inch thick, requires many months.

The hard fibers are used in electrical apparatus wherever an insulating material of exceptional mechanical strength is required, such as wedges in armature slots and coil braces, and as bushings around brush arms, etc.

ASBESTOS*

As stated above, one of the great disadvantages of the use of any material formed from organic fibers lies in the fact that such materials will carbonize and lose both their mechanical and their dielectric strength at comparatively low temperatures. Where operation at higher temperatures is essential, asbestos in the form of cloth or paper is sometimes used. Unfortunately the asbestos fiber is so short and lacking in mechanical strength that it cannot be made into thin cloth or paper without the addition of some longer fiber. As this must necessarily be an organic fiber the resulting fabric is more or less subject to the same objections as the pure cotton cloth. An idea of the amount of adulteration in asbestos cloth can be ob-

*See article on "Asbestos," by Mr. H. R. Edgecomb in the JOURNAL for Jan., 1911, page 82.

tained by noting the difference in mechanical strength before and after heating it to red heat. Another feature which limits the use of asbestos cloth is its low dielectric value and the difficulty of thorough impregnation, as the fibers themselves do not readily absorb varnish. Consequently asbestos cannot be used where high dielectric value is desired.

MICA

Where insulation must maintain high dielectric strength at high temperatures, mica is the only material that is at all suitable. It forms an ideal material from these standpoints, but owing to its poor mechanical properties is limited in its applications. Mica is an anhydrous silicate of aluminium and potassium or sodium which crystalizes in laminated form and may be split along its axis into very thin sheets. It is a very widely distributed mineral, being found in varying quantities in practically every country in the world. Deposits which are free from conducting material, however, are not so numerous, being confined to a few localities, among which the principal ones are in India, Canada and the United States. Of the mica that is mined even in these places, only about five percent is available for the building of sheet insulation, the rest of it being too badly broken to be of any use. This broken portion is ground still finer and is used in making decorative paint, in heating apparatus as a heat insulator, as a filler for various moulded compositions, and for various other purposes.

Mica as it comes from the mines for use in making sheet is split up into flakes which are graded No. 1 and No. 2. The No. 1 splittings are from .0005 to .001 inch, and the No. 2 from .001 to .002 inch thick. The No. 1 splittings are used in making up the flexible sheet by sticking them on one side of a sheet of paper or cloth with some suitable varnish in such a manner that all joints are staggered. These built up sheets are called "Jap. paper and Mica," "Fish paper and Mica," "Treated Cloth and Mica," etc., depending on the supporting sheet. They are used principally as insulation on generator and motor coils which must withstand high voltages, and are liable to be subjected to high temperatures.

The No. 2 splittings are built up in the same way on some cheap supporting paper. They are then placed in a press and heated under heavy pressure, driving the solvent out of the varnish used and forming a hard, rigid sheet. This material is called mica plate, and can be made in any thickness. It is used for commutator insulation, and in any place where heavy pressures must be withstood.

ARTIFICIAL RESPIRATION

PRONE PRESSURE METHOD OF RESUSCITATION FROM ELECTRIC SHOCKS AND DROWNING

CHAS. A LAUFFER, M. D.,
Medical Director, Relief Department, Westinghouse Electric and Manufacturing Company

THE immediate effect of contact with an electric current of sufficient voltage is a suspension of respiration. This suspended animation may consist merely of a suspension of the respiratory function, or, in the severer shocks of longer contact or higher voltage, there may be a suspension of both the cardiac and respiratory functions.

In those occasional cases where the heart action has ceased, there will be no possibility of restoring the respiratory action by the methods of artificial respiration. Yet the artificial respiration should be begun immediately and should be persisted in, at least until a physician is summoned to ascertain with his stethoscope if the heart is beating. While the heart beats, there is hope. But the heart may be beating in the absence of a radial pulse; hence, even when no pulse is felt, the fellowworkmen are not justified in ceasing in their efforts at resuscitation.

There must be no delay; the efforts must begin the instant the patient is freed from the contact. A piece of dry board, or dry clothing; a rope, or clothing improvised as a rope, will enable a comrade to rescue him from the circuit. The man nearest to him must know how to perform artificial respiration for him until the rhythm of his respiration is reëstablished. He must have the oxygen of the air, or his heart will cease beating. There is no time to remove belts and neckties and to open shirt fronts; this can be done by another during the act of resuscitation.

For its simplicity and superior utility, we prefer the "Prone Pressure" method of artificial respiration,* illustrated in Fig. 1. The three essentials of this method to be remembered and practiced in anticipation of an emergency, are:—

I—The man is laid upon his stomach, face turned to one side, so that the mouth and nose do not touch the ground.

II—The operator kneels, straddling the patient's hips; or kneels by either side of the hips, facing the patient's head.

*See *Journal American Medical Association*, Vol. LI, No. 10, and *Collier's*, Vol. 41, No. 25.

III—The operator places his spread hands upon the lower ribs of the patient and throws his own body and shoulders forward, so as to bring his weight heavily upon the lower ribs of the patient.

The operator's downward pressure should occupy about three seconds, then his hands are suddenly removed. Squeezing the chest in this manner forces the air out of the lungs. On release of the pressure the elasticity of the chest walls causes them to expand, and the lungs are refilled with fresh air.

This act should be repeated indefinitely at the rate of about twelve times a minute—the danger is that in the excitement of the occasion, the rate will be too rapid. If the operator is alone with

FIG. 1—PRONE PRESSURE METHOD OF ARTIFICIAL RESPIRATION

the patient, he can adjust the rate of the artificial respiration by his own deep regular breathing; if more persons are present, a watch can be used to advantage to regulate the rate. In all cases the efforts at resuscitation should be continued until the arrival of the physician. Any evidence of returning breathing should encourage the operator to continue his efforts. It often requires one-half hour to two hours; in cases of drowning, especially, it is advisable to keep at it, for recoveries have resulted after three hours of continuous artificial respiration. The physician can determine if the heart is beating, and whether or not continued efforts at resuscitation would be futile. The victim should have the benefit of the doubt if any exists.

An operator can learn to become expert by practicing on his friends—and they on him—until he knows what constitutes the essentials in the art of artificial respiration. By this method even a child can operate on an adult and maintain sufficient inflow and outflow of air (tidal air) to supply him with as much air as he would secure were he able to breathe voluntarily.

The prone position of the patient allows the tongue to fall forward, and permits water and mucus to escape from the mouth; for this reason the prone pressure method is the ideal method of resuscitating the drowning, for there is no loss of time in first pressing out the water, as by the old method. Edema of the lungs (accumulation of blood stained serum in the air vesicles and bronchioles) sometimes complicates the profound collapse of electrical shock; hence this method, as it allows the blood-stained mucus to flow out, is to be preferred. Furthermore, as an operator can work without exhaustion for an unlimited length of time by this method, there is no need of team work and working in relays, as, for example, with the Sylvester-Laborde method.

If the operator is alone, the artificial respiration is his chief concern and offers the only hope for the victim; yet, if there are others to assist, there are measures supplemental to the artificial respiration that may be carried out.

I—Aromatic Spirits of Ammonia, on gauze or cotton held near the nose, stimulates the respiratory function—is even more useful than oxygen—yet is valuable only as an adjunct to the other measures.

II—A dash of cold water in the face.

III—Spanking the buttocks.

Should the respiratory function continue in abeyance, the physician, upon his arrival, may render great assistance by the hypodermic administration of Atropine Sulphate gr. 1/100 and Strychnine Sulphate gr. 1/30, which can be repeated at his discretion, or he can stretch the sphincter ani.

No liquid should be given by the mouth to a patient in shock, or with suspended activity of the reflex nerve centers from any cause: if given under these conditions it is more liable to enter the lungs than the stomach.

Electrical accidents, as encountered in the industrial applications of electricity, may be classified as: first, flash injuries, embracing burns of the eyes and the skin, and second, contact injuries,

embracing suspended animation and burns often of a severe character. The even brief consideration of these several types of injuries is not within the scope of the present article, and, as they require the attention of the surgeon, it is understood that the patient for whom artificial respiration has been done, if he be simultaneously burned by the contact, will subsequently need the surgeon's care, as the healing of such electrical burns is in some cases quite tedious.

In the language of E. A. Schafer, Professor of Physiology in the University of Edinburgh, the prone pressure method of artificial respiration "proves to be completely efficacious and capable of effecting an air exchange greater than that produced in normal respiration." This conclusion was reached after all other known methods had been experimented with and found inferior, in the investigations carried out under the auspices of the Royal Medical and Chirurgical Society of London of whose committee Professor Schafer was chairman.

The prone pressure method has received quite universal recognition and in England has been officially adopted by the Royal Humane Society, the Royal Life Saving Society, and the Coastguard Service. One can acquaint himself with the method in ten minutes, and such serious consequences result from delay in case of suspended respiration that ignorance is inexcusable, especially among electrical men. The practice of the Westinghouse Electric & Manufacturing Company in holding weekly classes of instruction in the art of artificial respiration in order that all employees may familiarize themselves with the method may well be followed.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

525—Cost of Illuminants—Referring to "Historical Exhibit of Lamps," in the JOURNAL for Dec., 1910, p. 983, in which is given a list of various illuminants with cost per candle-hour, please advise on what rates for gas and electricity, respectively, these costs are based. S. R. I.

These costs are based on the regular rates for residence service which obtain in Rochester, where the exhibit was presented, viz., 95c per M. cubic feet for gas, and 8c per kw-hr for electricity, H. W. P.

526—Instantaneous Direction of Currents in Three-Phase Systems—In determining the instantaneous direction of currents in a three-phase—three-wire and a three-phase—four-wire system, would you ignore the neutral in the second case and take it as in the first instance, i. e., the middle phase acting as a return for the other two phases? C. B. P.

In tracing out directions of current in three-phase—three-wire circuits it is not necessary to deal with instantaneous currents. The only necessary assumption is that the current (at 100 percent power-factor) in one of the lines having a series transformer, is nearly in phase with the e.m.f. from that line to the one that has no series transformer. For the purposes of the diagram it is properly assumed that the current is exactly in phase with the voltage and the connections between these two lines may be treated as simply as if the circuit were for direct-current, assuming that the line without a transformer is the return line. For three-phase—four-wire circuits, however, it is necessary to consider the instantaneous direction or phase relation between the various currents and e.m.f.'s. See section on "Assumptions Regarding Positive Direction of Currents, in "Meter and Relay Connections," p. 260, May, 1908, and article on "Vector Diagrams Applied to Polyphase Connections," June, 1908, p. 341. H. W. B.

527—Error in Wattmeter Measurement Due to Phase Relations—Will the power measured by a wattmeter whose current connections are made through series transformers on the primary side of the power transformer and whose potential connections are made through shunt transformers on the secondary side be as accurate as when both current and voltage connections are made on the secondary side? In the case in question, the power transformers are in three-phase—two-phase connection and the meter shunt transformers are similarly connected, as shown in Fig. 527 (a). R. N. A.

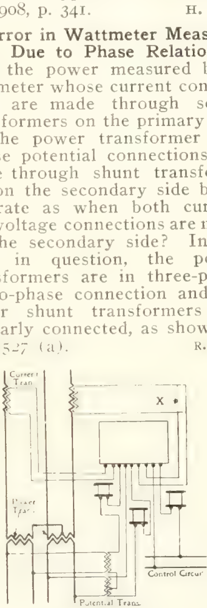


Fig. 527 (a)

One of the meter transformer connections should be reversed as shown by dotted lines at x in the diagram in order to give correct relation between the currents in the voltage and current windings of the wattmeter. The wattmeter will then register correctly, provided the 50 percent and 86.6 percent taps are correctly made on the wattmeter shunt transformers, if the power-factor is high and

the load is small. Increase of load increases the impedance drop which causes a displacement between the primary and secondary voltages of the power transformers from their normal phase relation to each other which in turn causes a corresponding phase displacement between the primary and secondary currents from their normal phase relation to each other. With decrease of power-factor of the load the effect of the change of phase relations noted above is increased. H. W. B.

528—Application of Direct-Current and Alternating-Current Motors —The following five types of motors are on hand: Series, shunt, compound direct-current, three-phase induction motor and single-phase motor. The power circuit is 110 volts, 60 cycle alternating-current. For what use is each of the above types of motors best suited? Which would be most suitable under the following conditions: *a*—Starting under no load, load being applied after speeding up; *b*—Starting under load; *c*—Operating with constant load at constant speed; *d*—Operating under condition of greatly varying load at constant speed; *e*—Operating with constant load at varying speed.

W. S.

Direct-current motors, such as those of the three types mentioned, are suitable for operation only on direct-current circuits. A three-phase motor is suitable for operation on a three-phase alternating-current circuit. A single-phase motor is suitable for operation on a single-phase circuit or on one phase of a polyphase circuit. In the latter case attention must be given to the question of balancing of total load on the respective phases if the best operating conditions are to be effected. The voltage of the circuit on which a given motor is operated must, of course, be approximately the same as that for which the motor is designed. Specific information regarding the applicability of various types of motors, both alternating and direct-current, is given in various articles which have appeared in the JOURNAL and referred to in The Seven Year Topical Index.

The following may be stated briefly regarding the five operating conditions named in the questions: *a—direct-current*,—shunt or compound; *alternating-current*,—single-phase or polyphase squirrel cage induction motor, synchronous motor. *b—direct-current*,—series or compound; in the latter case the series field may be cut out if constant speed is desired with varying load; *alternating-current*, — polyphase induction motor with phase-wound secondary or with high resistance squirrel cage secondary, single-phase series motor. *c—direct-current*,—series, shunt or compound; *alternating-current*, — squirrel cage induction motor, either single or polyphase, or synchronous motor if suitable starting arrangements are provided and it is not required to start under considerable load; otherwise as in *b*. *d—direct-current*, —shunt; *alternating-current*,—squirrel cage polyphase induction motor. *e—direct-current*, adjustable speed shunt or compound motor; *alternating-current*, — multi-speed polyphase induction motor for several definite speeds only; polyphase induction motor with phase-wound secondary (very inefficient for any great speed reduction.)

M. W. B. & A. C. L.

CORRECTIONS

In the article by Mr. G. M. Eaton in the Dec., 1910 issue the cuts of Figs. 10 and 11, p. 946, were interchanged.

Referring to page 986, Dec., 1910, the sixteen lines adjacent to Fig. 4 should read as follows:—"In this instance the 100 000 volt range comes exactly correct, but the 50 000 volt range gives 46 000 volts for full scale. By reference to the curve it may readily be seen that the meter will give fairly accurate readings for voltages as low as 10 000 volts, which gives a deflection of ten percent of the length of the scale when the 50 000 volt range is used."

THE
ELECTRIC JOURNAL

Vol. VIII MARCH, 1911 No. 3

An Ideal Modern Switchboard Installation

The characteristic features of the new switchboard installation of the Congressional Heat, Light and Power Plant at Washington, which particularly impress one in reading the article by Messrs. Sanderson and Turpin in this issue are the adaptability, flexibility and serviceability of the switching equipment in meeting the needs and requirements of such an important and special application. Continuity of service has been given first consideration in laying out this plant and its substations, and was one of the prime objects influencing the selection of the design of measuring, controlling and protective devices.

It is important to note the neat, and even artistic, appearance and arrangement of the entire installation. The particular type of high-tension, electrically operated, solenoid type of oil circuit breaker which was employed lends itself readily to a uniform and compact construction, as does also the detail apparatus for operating the high-tension bus-bars, including the sectionalizing, knife blade disconnecting switches and the high-tension current and voltage transformers. On the panels, one is particularly impressed by the uniformity in design of the indicating meters, with the full, open face and the clear, distinct marking of the dials, which is very easily obtained because of the unusual length of the scales. The adaptability of the switching equipment is clearly shown in the various illustrations.

Because of the foresight and careful attention to details from the standpoint of application to actual service conditions, which are embodied in all of this apparatus, it was feasible to use standard equipment throughout. An important feature of the power station switchboard equipment is that the high-tension circuit breakers, meter transformers, insulators and supports for the high-tension bus-bars and wiring on the lower floor are arranged so as to be completely separated from the low-tension control equipment, which, with the necessary meters and low voltage wiring, is mounted in the gallery immediately above. It will be noted that the panels contain all the instruments for measuring the power gen-

erated and distributed, and all the control switches for the various machines and circuits; thus, from this vantage point, the switchboard chief can operate the entire system. Considering the power to be handled, the compactness and simplicity of the whole arrangement is remarkable.

A possible complication, which might have resulted from the necessity of having practically two complete and separate stations in one, is easily avoided, because the switching equipment and controlling devices readily lend themselves to any multiplicity of combinations, thus emphasizing their flexibility.

The service rendered by the equipment must be sure and positive, and for this reason it has been selected from the standpoint of mechanical ruggedness and ample carrying capacity, which insures the serviceability of the switches and circuit breakers for handling all reasonable conditions of load—and unusual conditions in case of accident on any part of the system. All the apparatus furnished has clearly demonstrated its ability to fulfill these requirements, not only in this particular installation, but through satisfactory service in other stations of equal or larger capacity.

K. E. Van Kuran

Potential Stresses in Transformers

There are three sources of abnormal potential stress in a transformer. First—the type of stress perhaps most dangerous and least capable of calculation, which occurs between turns or between layers of a transformer winding due to the impinging of a moving charge against the windings. Such charges usually come from the line and are caused by static or electro-magnetic disturbances on the line. Stresses of this kind have been discussed in a descriptive way at different times but no accurate calculation of their magnitude has ever appeared. Second—Potential stresses between coils and between windings and ground due to the action of the windings, insulation, iron, etc., as condensers. These stresses have been generally recognized. The article in this issue entitled "Electrostatic Stresses and Ground Connections," by Mr. Fortescue, gives an analysis of their characteristics and by means of potential diagrams makes plain the relative and possible values of such stresses.

Two noteworthy facts appear from Mr. Fortescue's paper. One is that potential stresses due to capacity are by far the most

important as relating to the insulation of the low voltage side of a transformer and are then of chief importance when the ratio of transformation is large. The other is that if the relation of the windings is such that the adjacent coils have potentials of the same polarity induced in them, the maximum sum of the potentials due to normal e. m. f. and to induced static potential from adjacent windings will be very materially less than if the relation of the windings is the reverse.

The first point is of importance in indicating when special provision against these capacity stresses, such as by grounding the low voltage neutral, etc., should be resorted to. An example of this point is that of a 11 000 to 220 volt transformer. Should either side of the high-tension circuit break to ground the maximum stress on the high-tension winding would be but 11 000 volts. The insulation of the low-tension or 220 volt winding, however, which has often been assumed to be stressed to a maximum of but 220 volts, may in reality be subject to a much higher stress, even as high as one-half of the high-tension voltage. This has a direct application to service distribution, as excessive static stress may appear in certain cases on the lighting circuits with even a 2 200 volt primary and become much more serious in case the primary voltage is as high as 11 000, as sometimes occurs. Polyphase grouping of transformers introduces a new problem and may still further augment the possible danger.

The second point referred to has an important bearing on the insulation test which should be required between high and low tension windings and between low tension windings and ground. This second question, that of polarity of windings, is of chief importance when the voltages are high and the ratios low. For example, in a 66 000 to 6 600 voltage transformer, whether the test is based on the high-tension rating or on the sum of both the high and low voltages is not of vital importance. If however the ratio is 66 000 to 33 000, it makes a great difference whether the polarity is positive or negative, that is, whether adjacent windings develop e.m.f.s of the same sign and therefore have a relative stress which is due to the difference of their values, or whether they develop e.m.f.s of opposite polarity giving relative stresses due to their sum. With the assumptions in the article, a single-phase, ungrounded neutral system with transformer ratios of 66 000 to 33 000 would give, in case of a high-tension ground, a stress between high-tension and low at the terminals of adjacent groups of the respective

windings equal to 66 000 volts with positive polarity, or 33 000 volts with negative polarity. The relative polarity may have, therefore, a marked influence on the desirable or necessary insulation tests of the transformer.

A third form of stress will, we understand, be discussed in a later paper, by Mr. J. S. Peck. The stresses described by Mr. Peck are of purely electro-magnetic origin and are caused by faulty or disturbed connections of the windings of different transformers. While these stresses are liable to be excessive under particular conditions, they do not often occur in practice.

With the extremely high voltages now coming into use, the information given by Mr. Fortescue and Mr. Peck is important as it serves to indicate safe and unsafe ways of winding and connecting transformers. R. P. JACKSON

Mid-year Convention A. I. E. E.

The recent mid-year convention of the American Institute of Electrical Engineers, organized and very successfully conducted by the Pittsfield and Schenectady Sections, demonstrates the growing strength and activity of the sections, and indicates the new part they promise to take in the activities of this national society. As distances in this country are so great that only a small proportion of the members attend the annual convention, local conventions held in different localities fill a distinct need. A southern convention held in Charlotte about a year ago, was followed soon after by one on the Pacific coast. The average enrollment at the three local conventions has exceeded that of either of the last two annual conventions. The local conventions are not strictly local, the enrollment at the one last month including twenty-five percent of members from a distance, representing fifteen states and two foreign countries.

The papers, discussions and general interest in the two local conventions which have been held in the East, have been about on a par with the sessions of the annual convention.

Of special interest at the recent convention were papers relating to high-tension operation and to transformer construction. In quite a number of the papers oscillograph records took a prominent place, thus indicating present methods of investigation and the new field which this instrument has opened up. The device described

by Mr. Creighton for suppressing an arc over an insulator between a high-tension wire and ground, has been put under practical tests on the circuits of the Southern Power Company. These tests were described in a paper by Messrs. Burkholder and Marvin. The object is to extinguish the arc before it has time to do any damage. The method is to short-circuit the arc between wire and ground by the closing of an oil switch in the station by means of an automatic relay. The current is thus diverted from the arc to the switch, whereupon the arc ceases; the current through the switch is then immediately interrupted by the opening of the switch.

Mr. Nicholson of the Niagara, Lockport & Ontario Power Company described a somewhat similar method which he had devised and employed, in which the arc is suppressed by diverting the current through a fuse instead of a circuit-breaker. He found that a short-circuit on a 60 000 volt line could be made and broken in five cycles, or one-fifth of a second, which is so short a time that synchronous apparatus upon the circuit was unaffected.

These two reports of tests which have been going on simultaneously and independently indicate a substantial advance in power transmission by preventing the interruptions to service which flash-overs on the line have caused. This weakness has been one of the most serious in power transmission work, for although station apparatus might be made immune to the effects of lightning and static disturbances by the use of lightning arresters, in case of a flash-over on an insulator there has apparently been no practical means of preventing a momentary interruption to service or more serious consequences if a remote insulator be destroyed. When an arc over a high-tension insulator, possibly 100 miles from the power station, can be instantly suppressed by comparatively simple apparatus in the station and a short-circuit on a transmission system removed so quickly as not to affect the operation of sensitive apparatus, a notable advance has been made.

In the session devoted to transformers, nearly all of the time was given to the self-protection of transformers from high temperatures on the one hand and from mechanical injury, resulting from short-circuits, on the other.

In the consideration of the cooling of transformers by various methods, it is interesting to note that air-blast transformers seem to have dropped out of view. Air currents were not even considered as an auxiliary in connection with self-cooling transformers. Artificial ventilation applied to the exterior of transformer cases

or to small rooms in which transformers are located could aid materially in maintaining low temperatures.

The second topic relating to mechanical injury to transformers due to the mechanical forces produced by reaction between the currents in the coils when these currents are excessive, has become important owing to the increase in the size of generating stations and to the low inductance of large transformers, all of which tend toward excessive current in the transformer coils when there is a short-circuit on the secondary circuit. These forces are liable to distort and injure the coils unless they are rigidly supported.

Instead of striving now to secure the best possible inherent regulation, a reasonable amount of inductance in generators and in transformers or in an external choke coil is advocated as a means of limiting the current on short-circuit. Experience has shown that not only transformers but oil switches and lightning arresters, which have given years of satisfactory service in fairly large plants, have failed on very large power systems, due to excessive short-circuit current. The question naturally arises whether such a failure should be classed as defective design. Surely the designer for present conditions cannot be expected to provide against the most severe conditons which growth in generators and generating stations may bring about. It is important, however, that the designer should know definitely the conditions which are to be met and should be able to predict what his apparatus will do under these conditions.

CHAS. F. SCOTT

Steam Power Plant Economy

The operation of steam power stations for highest economy may involve other features than low steam consumption of the prime movers. Several points, frequently lost sight of, are brought out in Mr. Dreyfus' article in the present issue; certain of these merit special attention. Evidence is given under "Operating Conditions," for example, that the highest possible economy of the prime mover itself does not necessarily achieve the highest over-all plant economy. Moreover, the turbine or engine with the lowest steam consumption may not actually possess the highest efficiency as a heat transforming mechanism. Manifestly, the actual steam consumption of the main unit in any power plant has to be carefully considered in the endeavor to obtain

low operating costs, but the investment, maintenance and operative features must be correspondingly and adequately reckoned with. There are obvious economic limits in operating conditions, and the gain through low steam consumption of the main unit may be counterbalanced by the other items. It is beyond question, in this country, where coal seldom exceeds \$3.00 per ton, and more especially in the larger stations, that in a plant designed for 200 pounds steam pressure and 200 to 300 degrees superheat, the increase in maintenance and operating costs, over the use of 175 pounds pressure and 100 degrees superheat, would more than offset the saving at the coal pile, although in the one case the water rate would be 12 and in the other 14 pounds per kilowatt-hour. Similarly, the attempt to maintain high vacuum may easily neutralize any gain in steam consumption.

In analyzing the results of tests on steam turbines and engines, too great care cannot be given to keeping in mind the range throughout which the unit is working or, in other words, the energy which is available to be converted by the unit into useful work. Thus, an engine operating non-condensing with a water rate of 20 pounds per brake horse-power, when operating between 150 pounds steam pressure and atmospheric pressure, has a better efficiency than an engine with a water rate of 14 pounds per brake horse-power, but operating condensing from 150 pounds pressure to 28 inches vacuum. Hence, if use can be found for the steam after leaving the engine which is operating non-condensing, the overall economy of the station may be improved. Thus, operating the unit non-condensing and utilizing the exhaust for heating or industrial purposes, is more advantageous than operating condensing merely to effect a lower steam consumption.

The question often arises as to why performances obtained in the United States are not comparable with the 11.9 or 12 pounds per kilowatt-hour which are quoted in European tests. As pointed out by Mr. Dreyfus, these figures mean nothing unless accompanied by a statement of the operating conditions. The rate of 11.9 pounds per kilowatt-hour, quoted in the A. E. G. Rummelsburg tests, means that only 65 percent of the available heat energy is transformed into useful mechanical work, whereas the rate of 14.57 pounds per kilowatt-hour, obtained on the City Electric Company's machine in San Francisco, shows 69 percent efficiency ratio, i. e., an improvement of six percent, notwithstanding its steam consumption is 22 percent greater. W. B. Flanders

SWITCHBOARD OF CONGRESSIONAL HEAT, LIGHT AND POWER PLANT

WASHINGTON. D. C.

C. H. SANDERSON and M. C. TURPIN

IN no other class of apparatus has the remarkable development in the field of electrical apparatus during the last few years been more clearly exemplified than in that of switchboards. From a crude structure having mounted thereon all of the control devices then in use, such as knife switches with possibly some form of lightning protection and a few meters, the switchboard has expanded through the various stages of progress until it has

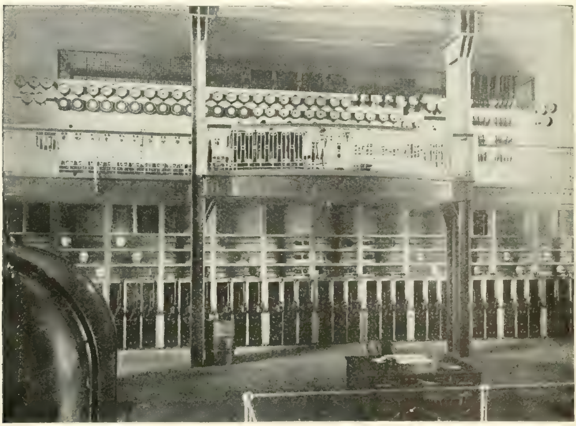


FIG. 1—VIEW OF GENERATING STATION SWITCHBOARD

Showing high-tension concrete structure and low-tension control panels.

reached its present state of excellence and appears as an elaborate structure of masonry and marble built in two or more sections on as many elevations and arranged for the control of high voltage apparatus which may be located at some distant point.

A most interesting example of this progress in the growth of switchboard manufacture is furnished in the history of the plants which have been supplying electric energy to the group of public buildings on Capitol Hill at Washington. The first electric plant

was installed in the Senate wing of the Capitol in 1887 and consisted of two Westinghouse "650 light," 1 000 volt, 133 cycle alternators. Later, two "350 light" machines were installed in the wing devoted to the House of Representatives.

The switchboard which was used for the control of this equipment, when compared with modern switchboards, well illustrates the rapid progress made in the manufacture of electric apparatus. It consisted of tongue and grooved three-inch by four-inch flooring. The framework was put together face downward on the floor near the final location of the completed switchboard and the wiring was then mounted on the rear of the board. The board was then securely nailed against the wall, leaving no intervening space. There were no bus-bars; solid copper wires were used, each machine being connected directly to the lighting circuits through the necessary knife switches.

The increasing use of electricity as an illuminant led naturally to requests for additional lights, with the result that the two plants

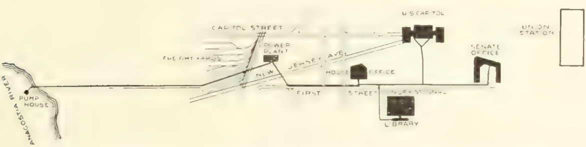


FIG. 2—SKETCH SHOWING LOCATION OF GENERATING STATION, SUB-STATIONS AND PUMP HOUSE

were soon overloaded. In 1895 the old belt-driven machines in both plants were replaced by direct-connected engine-driven generators, and standard marble panel switchboards were installed. The two boards were connected by three feeders, each consisting of nine No. 0000 wires. This connection was made to enable either plant to assist the other in case of accident or repairs. Additional generating units, switchboard panels, and bus-bars were added from time to time to take care of the rapidly increasing load.

One particularly noteworthy fact about the plant which reflects credit on the management is that, notwithstanding all the changes and additions made from time to time, no interruption of service ensued. On three different occasions it was necessary to move the switchboards in order to install new ones, and so well planned and carefully executed were these undertakings that at no time was there any break in the continuity of service.

In the basement of the Congressional Library, which is undoubtedly the finest building of its kind in this country and probably in the world, a generating plant was installed to furnish steam and electricity for the building. The generators were of the 130 volt Siemens-Halske outside commutator type, driven by Ball engines. The switchboard consisted of six white marble panels with the usual equipment of switches, meters, and automatic carbon circuit-breakers. Five boosters for raising the voltage on the long heavy feeders were installed.

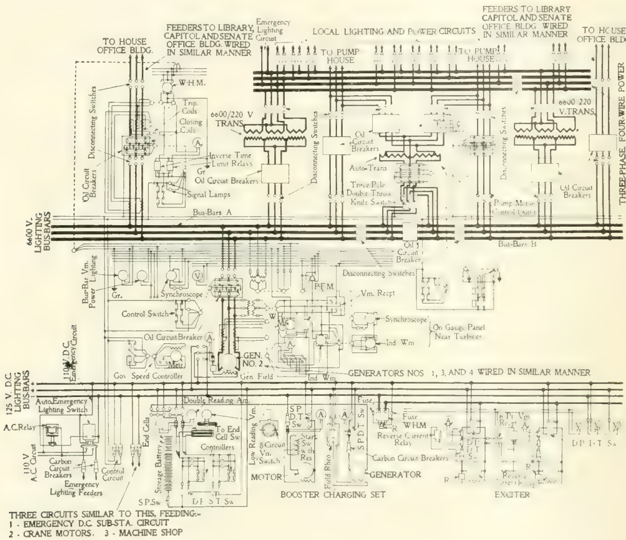


FIG. 3—DIAGRAM OF MAIN STATION SWITCHBOARD CONNECTIONS

Upon the erection of the handsome office buildings of the Senate and the House of Representatives at either end of the Capitol building, the question of supplying heat, light and power was naturally a very prominent one. After careful analysis of the costs, it was decided to build a central generating plant and furnish current and steam heat to the two new buildings and also to the Capitol and Congressional Library, thereby eliminating the three existing plants in the latter buildings.

Inasmuch as the two older buildings were wired for 110 volt direct current, having numerous motors of this type installed, it was decided to generate alternating-current and transmit it to sub-stations, one of which would be located in each of the four buildings, and at each of these points install motor-generator sets to deliver 110 volt direct current. In this manner a similarity of equipment could be maintained throughout the system. As practically all of the load on the generating station consisted of motors, and the maximum distance of transmission was nearly one mile,

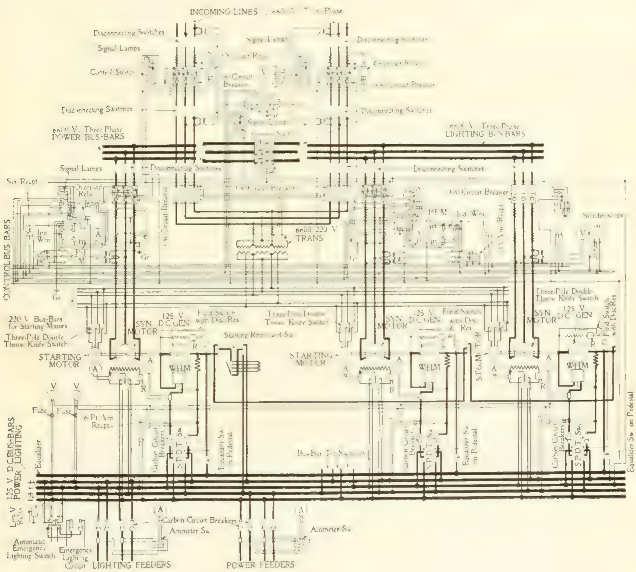


FIG. 4—DIAGRAM OF CONNECTIONS OF TYPICAL SUB-STATION SWITCHBOARD

6600 volt, 25-cycle generating equipment was installed. An additional reason for choosing this frequency and voltage was that they coincide with the local system of the Potomac Electric Power Company. This arrangement is of mutual advantage to the Government and to the local company, as each plant can furnish current to the other when desired. The main and sub-station boards are each equipped with a switch through which connection can be made to the circuits of the local power company. The Potomac

Electric Power Company furnished energy to operate the sub-stations previous to the completion of the main station, and energy has also been supplied to the local company by the Government plant at a time when it was desired to make repairs in the Bennings Power Plant.

The generating equipment consists of four 2 000 k.v.a. single-flow turbines and generators operating at a steam pressure of 175 pounds and under a vacuum of from 28 to 29 inches. Field excitation is normally furnished from exciters direct-connected to the turbines; a storage battery floats acrosss the exciter bus-bars for use

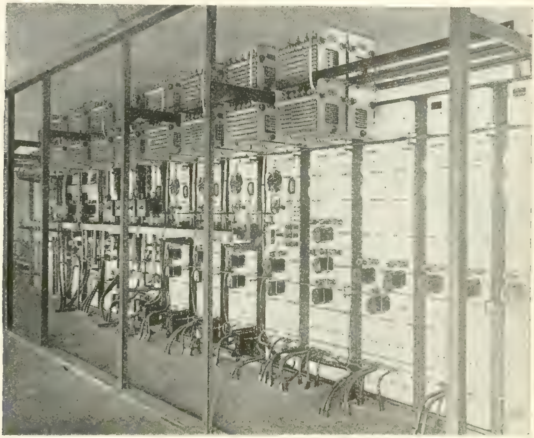


FIG. 5—REAR VIEW OF MAIN STATION PANEL BOARD
Showing low-tension wiring and rheostats.

in emergencies. Water for boiler feed and condensing purposes is pumped from the Anacostia branch of the Potomac River by one of two 20-inch centrifugal pumps installed in a pump house at the river. These pumps are driven by 250 hp, 6 600 volt vertical type induction motors controlled entirely from the main station switchboard. The power for the pumps is supplied through duplicate sets of three-phase cables from the power house.

Perhaps no feature in the design of the entire system better illustrates the precautions taken to provide continuity of service than the switchboards in the generating and sub-stations. The wiring scheme of the stations is given in the diagrams, Figs. 3

and 4; there are, however, several features which are not so readily apparent.

MAIN GENERATING STATION

The switching equipment divides the station into two equal parts of two 2 000 k.v.a. units each. Each of these parts may be operated as a separate and distinct station. One-half of each of the main 6 600 volt, three-phase bus-bars is termed the "lighting

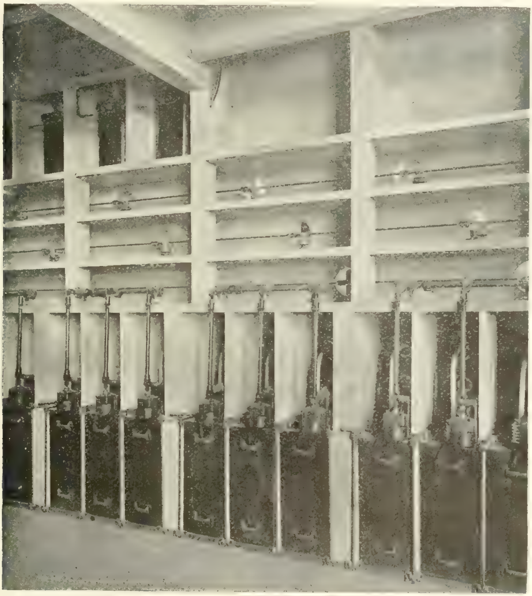


FIG. 6—DETAIL FRONT VIEW OF HIGH-TENSION CONCRETE STRUCTURE
Showing electrically operated oil circuit-breakers, bus-bars and voltage transformers.

bus" and the other half the "power bus," each supplying one of the duplicate feeders to each of the sub-stations and the pump house. Either half of the station is of sufficient capacity to furnish energy to the entire system when occasion demands. All four generators may supply all their energy to either the lighting bus-bars or the power bus-bars, but power load may be kept entirely distinct from the lighting load by operating the two halves of the

station separately, thus eliminating any objectionable fluctuation of the lights. It is obviously a simple matter to supply the output of energy of either half of the station to the local company without in any way interfering with the supply to the Capitol buildings.

The switching equipment consists of two parts; the nineteen panel white Italian marble switchboard and the high-tension bus-bar and circuit breaker concrete structure. The panel switchboard contains all the measuring instruments, controllers for the electrically operated circuit breakers, rheostats, and the main knife switches and carbon circuit breakers for the exciters, storage battery and auxiliary low voltage feeder circuits. The high-tension structure, located on the engine room floor, is built of standard cinder concrete reinforced by one-quarter inch steel rods.* It contains electrically operated oil circuit breakers with disconnecting switches, the current transformers and the oil insulated potential transformers with their primary fuses. All instrument and control wiring leaving the switchboard is carried in loricated iron conduit. The location of the switchboard immediately above the high-tension structure, as shown in Fig. 1, greatly simplifies the conduit system. The electrically operated oil circuit breakers consist of three separate poles, each mounted in its own compartment, as shown in Fig. 6, and interconnected both electrically and mechanically. The bus-bars consist

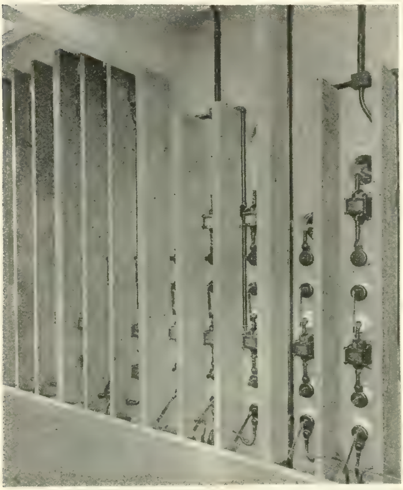


FIG. 7—DETAIL REAR VIEW OF HIGH-TENSION CONCRETE STRUCTURE

Showing current transformers, disconnecting switches and conduit wiring.

*For description of the design and method of building this structure, see article by Mr. W. R. Stinemetz on "High-Tension Concrete Switchboard Structures," in the JOURNAL for May, 1910, p. 373.

of bare copper rod supported from beneath by small porcelain petticoat insulators (See Fig. 6).

The four generator panels are located at the center of the switchboard with the exciter panels on the right and the high-tension feeder panels on the left. The auxiliary feeder, storage battery and motor-driven booster panels are at the right of the exciter panels. This arrangement divides the switchboard into two logical halves. The center of the switchboard is opposite the middle bay of the gallery which is extended to provide room for the operator's desk. The operator is thus nearest to that portion of the board which requires the most attention.

A set of low-tension bus-bars is installed to supply the local three-phase, four-wire lighting and power circuits, and, as in the case of the high-tension switchboard circuits, these are segregated by means of disconnecting switches into power and lighting bus-bars. Each half is fed through a group of three step-down transformers protected by an automatic oil circuit-breaker. A storage battery of 74 cells, having a capacity of 300 amperes for eight hours, is installed in the basement and floats across the exciter bus-bars, thus insuring uninterrupted excitation. The exciters are protected against excessive battery discharge by means of carbon circuit breakers equipped with reverse current relays which are set to trip the breakers at 20 percent reversal of current.

The switching scheme for excitation is double throw throughout, in keeping with the plan of having practically two separate plants. For charging the battery a motor-driven booster is provided. This booster consists of a 125 volt direct-current motor direct-connected to an interpole direct-current generator having a rating of 676 amperes at 65 volts. The set is located on the engine room floor immediately behind the high-tension concrete structure and is controlled from the gallery directly above.

In addition to the field excitation, direct-current energy is employed for the operation of the crane, ash handling machinery and machine shop motors and also for the emergency lighting circuits in the main station and each of the sub-stations. These emergency circuits are fed by separate pairs of cables from the main switchboard and comprise about one-fourth of the entire lighting in each station. They are controlled by solenoid switches which operate automatically on the principle of a no-voltage relay. At the sub-stations, the solenoids and emergency circuits are connected to the bus-bars. Should the direct-current voltage fail for any reason,

the solenoid plunger drops, causing the emergency circuit to be transferred to the storage battery.

The emergency lighting at the main station is connected normally to the alternating-current lighting bus-bars, and the solenoids of the emergency switches receive their energy from the direct-current bus-bars through the contacts of an alternating-current no-voltage relay. The emergency circuit is thus automatically transferred to the storage battery should the alternating-current voltage fail. At no time will there be any possibility of any of the stations being in darkness due to failure of the generating or transmission system.

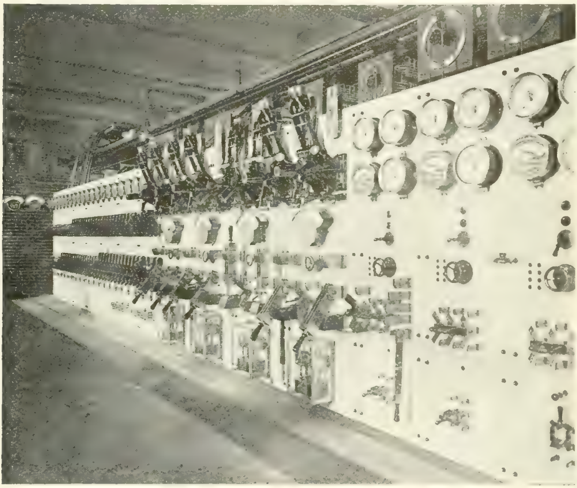


FIG. 8—TYPICAL SUB-STATION PANEL SWITCHBOARD

Control of Pumps—The operation of the induction motors installed in the pump house is controlled entirely from the main switchboard at the generating station, as noted above. The complete connections are shown in Fig. 3. The same pair of auto-transformers is used for starting both motors, the complete operation of starting the motor and connecting it to the 6600 volt bus-bars being accomplished by means of a single five-position controller designed specially for the purpose. The first position trips the main oil circuit breaker if it is closed when the operation of start-

ing the motor is begun; the second closes the auxiliary oil circuit breakers, applying the starting voltage through the auto-transformers; the third is "starting" position, the auxiliary circuit-breaker closing coils being disconnected from their source of power but the circuit breakers remaining closed; the fourth simultaneously trips the auxiliary circuit breaker and closes the main breaker connecting the motor to the main bus-bars; the fifth or "off" position opens the closing-coil circuit of the main breakers. Red and green indicating lamps, which indicate whether the cycle of operation is being properly performed, are provided for both starting and running breakers. The controller is provided with a ratchet which prevents reverse operation, thus eliminating the possibility of throwing the motor directly on full voltage. It is also provided with a spring which automatically returns it to the "off" position. The pump house is provided with the proper equipment of oil-break and disconnecting switches so that either motor may be connected to either of the duplicate feeder cables from the plant. No attendant is required in this station as normally the motors are controlled from the main switchboard. The oil switches and other auxiliary apparatus in the pump house, such as switches for the lighting circuits and five horse-power motor in the sump pit, are mounted on a black marine finished slate panel switchboard.

SUB-STATIONS

The four sub-stations, at the Capitol, Congressional Library, and the House and Senate office buildings, as well as the pump house, are each connected to the main station by duplicate sets of three-conductor, paper insulated lead-covered cables laid in vitrified tile conduits. The sub-stations are equipped with motor-generator sets each consisting of one 6600 volt synchronous motor direct-connected to and mounted on a common bed plate with one 400 kw, 125 volt compound wound direct-current generator and an induction motor for starting. The Capitol sub-station has five motor-generator sets; the House office building, four; the Senate office building and Congressional Library, three each.

The wiring diagram for all the sub-stations is, except for the number of machines, the same as that shown in Fig. 4. The high-tension switchboard panels and the oil circuit breaker and bus-bar structures for the sub-stations are of the same general design as those for the main station. The main alternating-current bus-bars are sectionalized by means of an oil circuit breaker and its disconnecting switches so that, as in the main station, each sub-station

may be operated as two independent stations or as a unit. Here again, with two complete sets of bus-bars, any or all machines can be connected to deliver current to either the lighting or the power bus-bars. The motor-generator sets may be started from either half of the alternating-current bus-bars by means of the starting motors, or if desirable any set may be started from either of the direct-current bus-bars.

In the summer time when the load is light the Capitol sub-station will be used as a distributing station and the others will

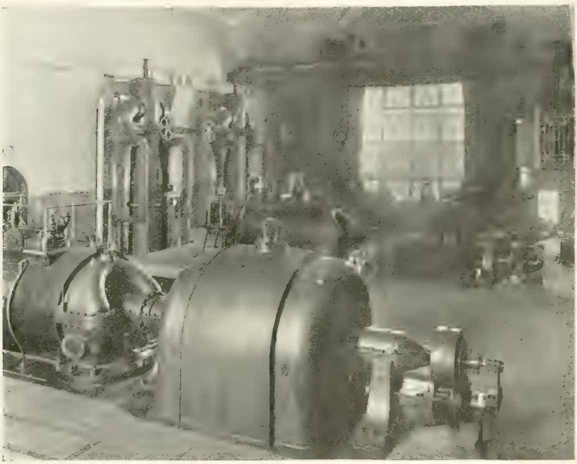


FIG. 9—INTERIOR VIEW OF GENERATING STATION SHOWING TURBO-GENERATORS AND CONDENSERS

Bay of switchboard gallery at right.

be shut down. To overcome the line drop due to direct-current distributed in this manner a booster set will be installed.

The Congressional power plant is under the supervision of Mr. Elliott R. Woods, Superintendent of Grounds and Buildings, and under the immediate supervision of Mr. C. P. Gliem, chief electrical engineer, to whom much credit is due for many of the advantageous engineering features adopted in this well equipped station. The engineering work was done by Westinghouse, Church, Kerr & Company. The Westinghouse Electric & Manufacturing Company furnished the generating and sub-station equipment, switchboards and motors.

HISTORY OF THE AIR BRAKE*

ITS CONCEPTION, INTRODUCTION AND DEVELOPMENT

GEORGE WESTINGHOUSE

MY first idea of braking apparatus to be applied to all of the cars of a train came to me in this way; a train upon which I was a passenger between Schenectady and Troy in 1866 was delayed a couple of hours due to a collision between two freight trains. The loss of time and the inconvenience arising from it suggested that if the engineers of those trains had had some means of applying brakes to all of the wheels of their trains, the accident in question might have been avoided and the time of my fellow-passengers and myself might have been saved.

The first idea which came into my mind, which I afterwards found had been in the minds of many others, was to connect the brake levers of each car to its draft-gear so that an application of the brakes to the locomotive, which would cause the cars to close up toward the engine, would thereby apply a braking force through the couplers and levers to the wheels of each car. Although the crudeness of this idea became apparent upon an attempt to devise an apparatus to carry the scheme into effect, nevertheless the idea of applying power brakes to a train was firmly planted in my mind.

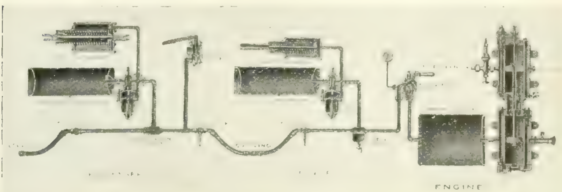
Shortly afterwards, while I was in Chicago, the superintendent of the Chicago, Burlington & Quincy Railroad, Mr. A. N. Towne, invited me to inspect what was then considered an ideal passenger train, namely, the Aurora Accommodation. I accepted this invitation and while looking over the train which was fitted with a chain brake, I was introduced by Mr. Towne to Mr. Ambler, the inventor of that brake. The Ambler brake, as was explained to me, consisted of a windlass on the locomotive which could be revolved by pressing a grooved wheel against the flange of the driving-wheel to wind up a chain which extended beneath the entire train over a series of rollers attached to the brake levers of each car and so arranged that the tightening of the chain caused the brake levers to move and thereby apply the brake shoes to the wheels. I ventured to say to Mr. Ambler that I had been working upon a brake myself, but was immediately informed by him that there was no use working

*Presidential address at the annual meeting of the American Society of Mechanical Engineers, New York, Dec. 6, 1910, condensed.

upon the brake problem, because he had devised the only feasible plan, which was fully protected by patents. Mr. Ambler's opinion and advice, however, proved to be an incentive to a more energetic pursuit of the subject.

As an improvement on Mr. Ambler's plan, I considered the use of a long cylinder to be placed under the locomotive, the piston of this cylinder to be so connected to the chain that it could be drawn tight by the application of steam from the locomotive boiler with a force which could be more accurately controlled than was possible with the windlass arrangement. A short study of this idea showed that it would be impossible to have a cylinder long enough to operate a chain brake upon more than four or five cars, whereas trains of ten and twelve passenger cars were frequently run upon the important railways.

My next thought was the placing of a steam cylinder under



THE WESTINGHOUSE SYSTEM NON-AUTOMATIC AIR BRAKE, 1869
Commonly known as the "Straight Air" brake.

each car with a pipe connection extended from the locomotive beneath its tender and under each car, with flexible connections of some sort, not then thought out, so that steam could be transmitted from the locomotive through the train pipe to all of the cylinders; but, as in the case of the attempt to improve the chain brake, it required but little time with some experimentation to disclose the fact that it would be impossible, even in warm weather, to successfully work the brakes upon a number of cars by means of steam transmitted from the locomotive boiler through pipes to brake cylinders.

Shortly after I had reached this conclusion, I was induced by a couple of young women who came into my father's works to subscribe for a monthly paper, and in a very early number, probably the first one I received, there was an account of the tunneling of Mount Cenis by machinery driven by compressed air conveyed

through 3 000 feet of pipes, the then depth of that tunnel. This account of the use of compressed air instantly indicated that brake apparatus of the kind contemplated for operation by steam could be operated by means of compressed air upon any length of train, and I thereupon began actively to develop drawings of apparatus suitable for the purpose and in 1867 promptly filed a caveat in the United States Patent Office to protect the invention. In the meantime, I had removed from Schenectady to Pittsburg, where I met Mr. Ralph Baggaley, who undertook to defray the cost of constructing the apparatus needed to make a demonstration.

At that time no compressed air apparatus of importance had within my knowledge been put in operation. The apparatus needed for a demonstration was, however, laboriously constructed in a machine shop in Pittsburg, being finally completed in the Summer or early Autumn of 1868. This apparatus consisted of an air pump, a main reservoir into which air was to be compressed for the locomotive equipment, and four or five cylinders such as were to be put under the cars, with the necessary piping, all so arranged that their operation as upon a train could be observed. Railway officials of the Pennsylvania and Panhandle railroads were then invited to inspect the apparatus and witness its operation. As a result, the Superintendent of what was then known as the Panhandle Railroad, Mr. W. W. Card, offered to put the Steubenville accommodation train at my disposal to enable me to make a practical demonstration. The apparatus exhibited was removed from the shop and applied to this train, which consisted of a locomotive and four cars. Upon its first run after the apparatus was attached to the train, the engineer, Daniel Tate, on emerging from the tunnel near the Union Station in Pittsburg, saw a horse and wagon standing upon the track. The instantaneous application of the air brakes prevented what might have been a serious accident, and the value of this invention was thus quickly proven and the air brake started upon a most useful and successful career.

In the development and introduction of the air brake, I was controlled by the apparent fact that the apparatus would have to be uniform upon all cars to provide for the convenient change of the composition of trains. It also was most obvious, in view of the crying demand for some better means for stopping trains, that some power brake would inevitably be universally applied to all of the cars and engines upon all railways. These ideas naturally involved a further one, namely, the importance of having all of the brake

apparatus made by one company, so as to insure absolute uniformity and consequent interchangeability, and this led to the formation of the Westinghouse Air Brake Company early in 1869.

The essential parts of the air brake as first applied were:

An air-pump driven by a steam engine receiving its supply from the boiler of the locomotive;

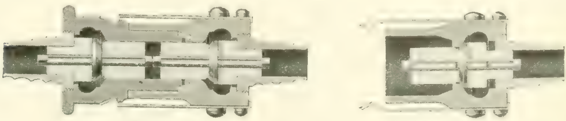
A main reservoir on the locomotive into which air was compressed to about 60 to 70 lbs. pressure per square inch;

A pipe leading from the reservoir to a valve mechanism convenient to the engineer;

Brake cylinders for the tender and each car;

A line of pipe leading from the brake valve under the tender and all of the cars, with a pipe connection to each brake cylinder.

Flexible hose connections between the cars provided with couplings having valves which were automatically opened when the two parts of the couplings were joined and automatically closed when the couplings were separated, so that the valve of the coupling at the end of the train was always closed and prevented the escape of air when introduced into the brake pipe.



Coupled—Check Valve Open Non-Coupled—Valve Closed

FIRST FORM OF HOSE COUPLING WITH CHECK VALVES
As used with the straight air brake of 1869.

The piston of each cylinder was attached to the ordinary hand-brake lever in such a manner that when the piston was thrust outward by the admisssion of compressed air, the brakes were applied. When the engineer had occasion to stop his train, he admitted the air from the reservoir on the locomotive into the brake cylinders through the train pipe. The pistons of all cylinders were, it was then supposed, simultaneously moved to set all of the brakes with a force depending upon the amount of air admitted through the valve under the control of the engineer.

To release the brakes, the handle of the brake valve was moved so as to cut off communication with the reservoir and then to open a passage from the brake pipe to the atmosphere, permitting the air which had been admitted to the pipes and cylinders to escape.

The success of the apparatus upon the first train was followed by an application of an equipment to a train of six cars on the

Pennsylvania Railroad, and in September, 1869, this train was placed at the disposal of the Association of Master Mechanics representing numerous railways, which association was then in session at Pittsburg. The train was run to Altoona and the air brakes were used exclusively for controlling the speed of the train on the eastern slope of the Alleghenies, and special stops were made at the steepest portions of the line in such an incredibly short distance (as we all thought then) as to firmly establish in the minds of all present the fact that trains could be efficiently and successfully controlled by means of brakes operated by compressed air.

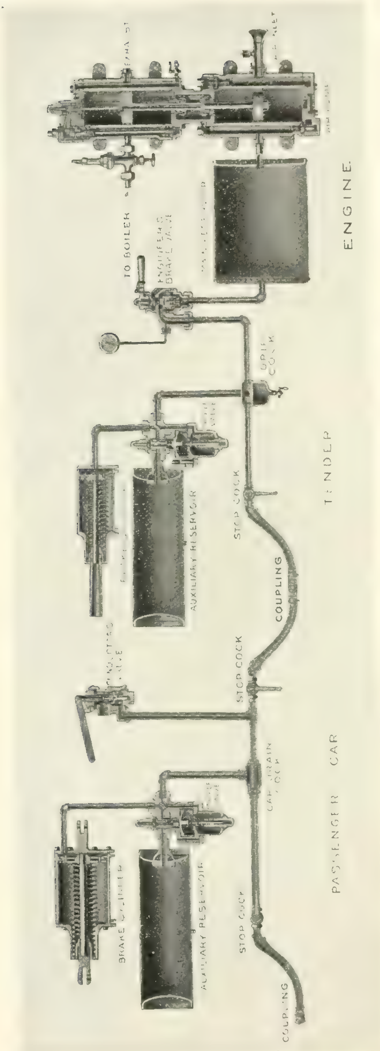
The next event of importance was the application of the brakes in November, 1869, to a longer train of ten cars upon the Pennsylvania Railroad, which was taken to Philadelphia for the purpose of demonstrating to the directors of that railway the success of the apparatus.

The apparatus was then transferred to a train consisting of a new locomotive and six new cars, and this train was run to Chicago over the Ft. Wayne Railroad, and a number of tests were immediately afterwards made upon the tracks of the Chicago & Northwestern Railway. The outcome of these demonstrations was immediate orders for equipment.

Works were built in Pittsburg for the manufacture of the apparatus and were fitted with the best tools obtainable. Standards were adopted and adhered to in the parts of the apparatus which required uniformity in construction in order to insure interchange of the rolling stock so fitted upon various roads.

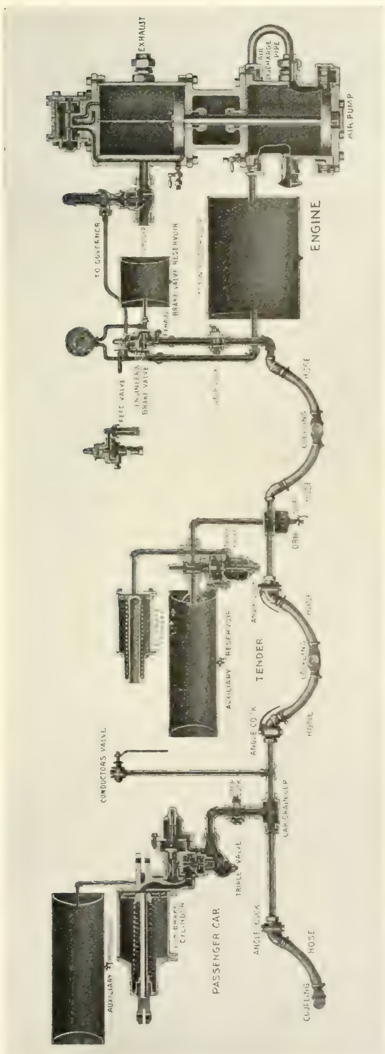
It soon developed that it took considerable time to apply the brakes with full force and a longer time to release them, and that in the event of a break-in-two of a train (a frequent occurrence in those days) the rear section would be uncontrolled, and when this occurred upon an ascending gradient, the rear detached section might run away with disastrous results. To overcome this difficulty a new development was necessary, the outcome of which was what has since been known as the automatic air brake.

In the automatic air brake equipment there were the same air-pump, reservoir, train pipe and brake cylinder, but in addition to these there were two important features added to the tender and each car equipment; the first, an auxiliary reservoir, and the second, a triple valve or device interposed between the brake pipe, brake cylinder and auxiliary reservoir. This triple valve was so con-



THE WESTINGHOUSE PLAIN AUTOMATIC AIR BRAKE, 1872

structed that when air was admitted to the train pipe, an opening was established between the train pipe and auxiliary reservoir whereby the train pipe and reservoir were filled with air under pressure. The valve also opened a passage from the brake cylinder to the atmosphere. This was the normal condition of the apparatus when the brakes were off. To apply the brakes, the engineer discharged a portion of the air from the train pipe, whereupon the triple valve closed the connection between the brake pipe and the reservoir and between the brake cylinder and the atmosphere and then opened a passage from the auxiliary reservoir to the brake cylinder, the piston of which was moved outwardly by the air



THE WESTINGHOUSE SYSTEM QUICK ACTION AUTOMATIC AIR BRAKE, 1887

from the auxiliary reservoir so as to apply the brakes. The restoration of the pressure within the brake pipe released the brakes and re-charged the reservoir. This development occurred during 1872 and 1873.

The automatic brake was at that time supposed to be instantaneous in its action in applying the brakes, and almost instantaneous in releasing them. In the event of the escape of air from the train pipe by its rupture or by the separation of the train, the air stored in the auxiliary reservoirs instantly and automatically applied the brakes to all parts of the train and they could only be released by either repairing the damage and restoring the pressure, or by means of special release valves operated by the trainmen.

The automatic brake having proved itself vastly superior to the plain or straight air brake first described, it soon became a standard, but during the transition period an automatic brake was easily converted into a plain brake by a manually operated special valve arranged in the casing of the triple valve. The gradual increase in the length of freight trains and the numerous accidents due to lack of brake control early suggested that automatic air brakes should be made a part of the equipment of all freight trains.

In 1885 the Master Car Builders appointed a committee to report upon the feasibility of the application of brakes to freight trains, and this committee inaugurated what are now known as the Burlington (Ia.) brake trials made in 1886 and 1887. There were presented two trains fitted with air brakes, one fitted with a vacuum brake and one with the brake operated by means of attachments to the drawbars similar to the conception first referred to. Each of these trains had fifty cars. These tests proved the inadequacy of the type of automatic air brake then presented by the Westinghouse Air Brake Company, as well as the inadequacy of all the other brakes then tested.

It becoming apparent that the lack of success at Burlington was due to the comparatively slow application of the brakes upon the rear portion of the train, the effect of which was to cause most serious shocks almost like collisions, a new development was imperatively needed in order to insure the successful handling of freight trains of fifty cars.

As a part of the automatic air brake passenger equipment, I had developed in the '70s a system of train signalling involving the use of a second train pipe which is now in general use upon all the railways. This signaling apparatus had a sensitive valve device connected to a small reservoir upon the locomotive and these were so arranged that when compressed air was admitted through a small opening into the signaling pipe, both the pipe and reservoir were charged to a low pressure (at the present time to 45 lbs.). By opening a valve at any point in the train to permit a small quantity of air to escape from the signal pipe, the delicate valve referred to was caused to move so as to admit air from its auxiliary reservoir to blow a whistle located in the cab of the locomotive. It was found upon experimentation that when the valve in any car remote from the engine would be opened and closed as many as

five times, the whistle would be blown an equal number of times, the first time being after the last escape of air; that is to say, there were set in motion five distinct waves of air each capable of doing work.

During these developments it was found that the waves of air within the brake pipe travelled as rapidly as sound, *i. e.*, about 1 100 feet a second.

Being fully impressed with the idea that if the wave of air which was utilized for signalling could be made to operate the triple valves upon the cars, there would then be an almost instantaneous application of the brakes upon the front, rear and other portions of the train, this idea, with hard work and a large number of experiments, shortly produced what is now known as the quick-action automatic brake. The Westinghouse train was left at Burlington in order that the new triple valves with the quick action attachment could be applied and further experiments made. The valves as developed for this emergency proved to be successful and the tests made with this train after their application were eminently satisfactory to the railway officials. This train, drawn by two locomotives, was frequently run at speeds above fifty miles an hour and the tests were witnessed by all of the prominent railroad people of the country. The wide publicity given to these tests, coupled with a public demand for the adoption of means to prevent accidents, brought about the enactment of a law by Congress obliging the railways to apply brakes and also automatic couplers to all freight trains in the United States. The quick action automatic brake was operated like the first automatic brake for ordinary train movements; the quick action resulted only when it was necessary to apply the brakes for an emergency.

No sooner had the quick action automatic brake been developed to operate successfully on trains of fifty cars than new conditions were presented. Steel freight cars carrying enormous loads had in the meantime been developed and freight locomotives had been increased in capacity, so that trains were often composed of seventy to eighty cars and more recently some trains have had as high as one hundred cars. This possibility had, however, been foreseen and experiments were constantly being carried on to so improve the apparatus that it could be used to control trains of any practical length, and these experiments also had in view the more nearly instantaneous action of the brakes for ordinary service purposes than was possible with the automatic brake or with the

quick action brake. The result was a most important development.

The present improved triple valve has the emergency feature, but it also has what is known as the quick-service application feature, that is for ordinary purposes the air is admitted to all of the brake cylinders so quickly that the longest freight train can be handled with almost the precision obtainable in the control of passenger trains of from six to twelve cars.

In the matter of the development of the brakes for operation upon passenger trains, nothing that skill and perseverance could suggest has been omitted in securing the highest degree of perfection. The requirements during the past few years, by reason of the greater weight of cars and locomotives and of the higher speeds at which they are run, have necessitated the re-designing of all of the passenger train brake apparatus, including the method of attaching the brake shoes to the cars and the levers and connections for bringing these shoes to bear with the required pressure upon the wheels. For the purpose of insuring the highest efficiency every wheel of a passenger train, including those under the locomotive, is now acted upon.

During the past twelve months, most elaborate tests of the latest form of apparatus for passenger service have been carried out under the direction of officials of several railways and of the Westinghouse Air Brake Company, in order to prove the operativeness of the new constructions and their capability to insure the highest degree of efficiency.

From the very beginning of its operations, the Brake Company has maintained a strong staff of experienced engineers, some of whom are located in each of the large railway centers and whose services are always at the command of the railways. It is the duty of one or more of these trained men to proceed to the scene of any accident that may have occurred in order to ascertain the cause, to report thereon and to render such aid and coöperation to the railway officials as will tend to avoid a like accident if in any manner the brake can contribute to that end.

The Air Brake Company has always had in its works, for experimental purposes, sets of brake cylinders, pipes and couplings, representing the apparatus upon trains of various lengths, so that tests and demonstrations could be readily made for all sorts of purposes, including educating or informing railway officials who came to seek information. To more effectively spread this information, the company about fifteen years ago constructed and

equipped a special instruction car in which were arranged fifty sets of brake cylinders and pipes equivalent to like apparatus upon a freight train. Operative models of all parts of the apparatus were shown in section. This car, in charge of experienced instructors, was moved from place to place, and engineers, firemen, conductors and other train employees in general visited it to familiarize themselves not only with the operation of the brake but with its construction. The records show that to December 1, 1910, the instruction car had travelled over 113 000 miles.

At a banquet given in Washington to the members of the International Railway Congress in May, 1905, a diplomat, in speaking on the subject of the importance of railway brakes, said he felt safe in saying the air brake had saved more lives than any general had ever lost in a great battle.

I have spoken of four chief developments. It has been necessary, in order to avoid disastrous consequences, that each development should be of such a kind that cars fitted with newer apparatus could operate with little inconvenience with cars fitted with earlier apparatus. As it stands today, scarcely any of the old type of brake and the first type of automatic brake are in use, but should a car fitted with the first form of automatic brake be found and put into a train with the more modern apparatus, such older apparatus would be found to operate fairly well with the more perfect form. The prevailing idea in the development and introduction of the brake has therefore been an adherence to such uniformity of apparatus that the interchange of traffic over various roads could go on uninterruptedly.

My story would be incomplete without a reference to the splendid assistance which the railways of this and many other countries have rendered. They have been lavish in providing those facilities for making the thousands of tests which were necessary to progress in the developments I have recited. To name the railways and to merely state chronologically the tests of brakes which have been made during forty years would require several volumes.

MOTOR APPLICATIONS IN THE TEXTILE INDUSTRY

ALBERT WALTON

THE history of the introduction of the small motor into the textile industry is very interesting. The industry is an old one; ideas have become fixed and textile machinery has been rigidly standardized. Mills have been running for over a century with but few radical changes in management or machinery. The power equipment increased in size and efficiency, but remained for generations the same in type and method of application. A large engine, usually located near the center of the long five or six story building, drives through ropes or belt

FIG. 1—208 SPINDLE, RING SPINNING FRAMES
Driven by 5-hp squirrel-cage motors

a jack shaft on each floor from which the power is distributed by heavy belts and shafting to the multitude of machines. Units of a thousand or two thousand horse-power were the order of the day. A new growth meant a new mill, practically a duplicate of the first. Father, son and grandson operated mills in hereditary succession and inherited with the property the ideas that were in vogue when they entered the active management. Eminently successful in production and in financial return, it was not easy to show wherein an advantage would accrue by any change, especially such a radical one as the introduction of a new method

of power distribution. To the operator accustomed to units of a thousand horse-power and realizing the advantages of these large

FIG. 2—PICKER ROOM—BELT DRIVE

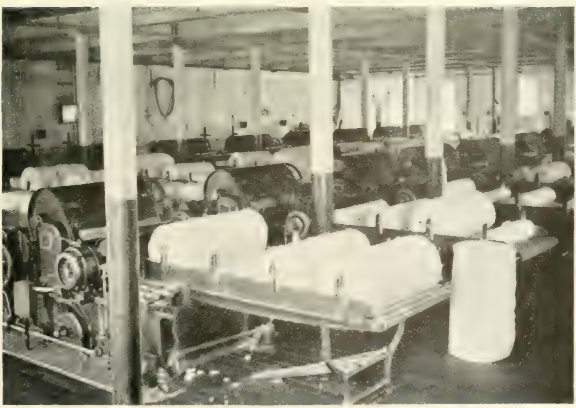


FIG. 3—PICKER ROOM—INDIVIDUAL MOTOR DRIVE

installations, a motor of two hundred horse-power seemed like retrogression. Adding to this the natural suspicion of so mys-

terious a force as electricity, a state of mind was produced hardly to be realized in this day of the small motor.

About twenty years ago a mill was equipped throughout with electric drive, receiving power from a water wheel station. Motors of fifty to one hundred and fifty horse-power were installed and operated successfully. The advantages of separation of departments and independence of operation were at once apparent and for fifteen years the system grew in favor with but little change. It was known as the group system and was eminently satisfactory, the ability to grow in any direction and by any increment being a potent factor in its development.

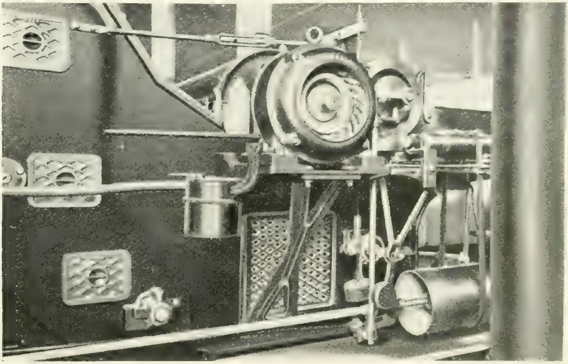


FIG. 4—PICKER DRIVEN BY TEXTILE MOTOR WITH SPECIAL BEARING
Showing same room as Fig. 2, after the change to individual drive.

The item of power saving was at first erroneously claimed by engineers as a prime consideration, but it was soon found that although there were many virtues to the drive not possessed by the more cumbersome engine drive this was not among them. Results from many reliable tests agree that a large mill can transmit its power by belt and shaft with a loss not exceeding twenty-two percent of the total. While the use of motors on the group system provided the desirable flexibility and independence, it still retained a large part of the old mechanical losses. The heavy belts or ropes from flywheel to jack shaft and jack shaft to line shafts were replaced by the electric system consisting of generators, wires and motors. The losses eliminated were replaced

by greater ones making a net loss in efficiency of power transmission. Overbalancing this, however, was the well known excellence of the drive viewed from other sides. The development of the steam turbine further accentuated these advantages and placed electric drive on a firm basis.

About six years ago a long series of investigations was made bearing on the use of small motors driving directly on the machines themselves without intervening transmission devices. After many vicissitudes and in the face of a complete apathy on the part of conservative mill operators and not a little active opposition from

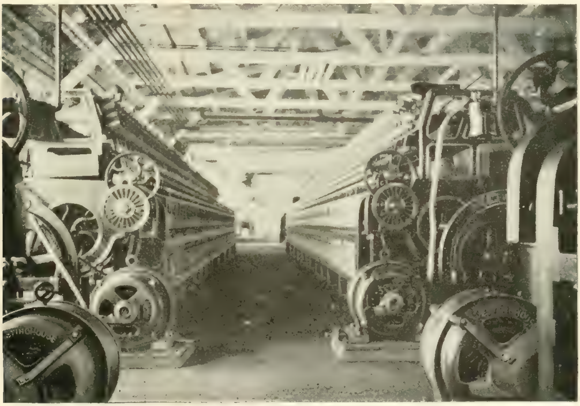


FIG. 5—WORSTED SPINNING FRAMES
Driven by 5-hp motors.

machinery manufacturers, a great amount of data and information was secured tending to show that the use of direct drive was eminently desirable. Eventually the special textile motor was brought out to meet the needs of the situation and demonstration drives were placed here and there among the mills. The success was immediate and gratifying; there was every reason why it should be. Textile machinery is run at high rotative speeds and an absolutely steady and uniform rate of rotation is demanded for best production.

In the cotton mills the spinning frame drives were first developed as the high speed of the driving cylinder or drum was conducive to direct connection to alternating-current motors. Fig. 1

shows the final development of this very successful application. Twenty motors of five horse-power capacity are shown driving ring spinning frames of 208 spindles each, spinning No. 26 yarn for sheetings. The motor is controlled by a special enclosed switch mounted on the end of the spinning frame and operated from any point along the frame by one of the handles plainly visible above each machine. As cotton lint is as inflammable as gunpowder, the fire risk had to be considered. It was not difficult with induction motors and oil immersed switches to eliminate this danger absolutely and no trouble has ever arisen from this source. The compactness of the drive is well illustrated in this view but only a

FIG. 6—WORSTED LOOMS
Driven by 1-hp textile motors.

visit to the room itself could give an idea of the remarkable uniformity of speed resulting. With turbine power back of the motors they do not vary one percent from the normal speed.

The pickers—the first machines to work the raw cotton—afford another example of an extremely compact, neat drive that has been developed along somewhat similar lines. The old standard method of driving these machines mechanically is well illustrated in Fig. 2. The forest of superstructure with its dirt and inefficiency, obstruction of light and high cost of upkeep has been eliminated by the direct drive shown in Fig. 3, a view in the same room from the same spot after the change to individual drive was made. In this case instead of inserting the motor shaft

into the revolving element of the machine as was done with the spinning frames, the heavy beater shaft is inserted into the rotor of the motor. There are 180 of these machines so driven in this one mill, probably the largest installation of its kind in the world. A special motor with an ultra-heavy bearing was designed for the purpose. This bearing, which forms an integral part of the motor frame, is bolted to the picker frame, replacing the picker bearing. The motor secondary is mounted directly on the beater shaft without cutting or altering the shaft in any way, since it must be turned end for end occasionally to bring the reverse edges of the blades into play. As shown in Fig. 4, no outer motor bearing is necessary.

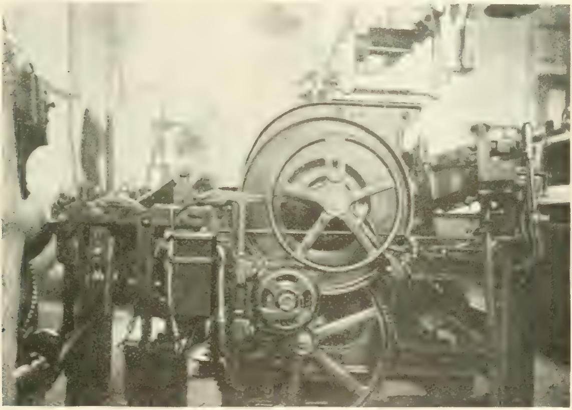


FIG. 7—SILK LOOM DRIVEN THROUGH SHOCK-ABSORBING FRICTION CLUTCH BY ONE-HALF HORSE-POWER MOTOR

Perhaps most surprising of all the developments in the cotton mill is that of an individual drive on a heavy cotton loom weaving fabric for automobile tires. One hundred and forty of these looms are thus driven in a Massachusetts mill. Here the parts are reciprocating and the rotative speeds are low but the benefits from a perfectly uniform speed are most marked, much less breakage of loom parts occurring on account of the possiblity of making much closer speed adjustments.

Although the principal effort in developing these drives was originally expended in the cotton mill field it has become no less popular in the wool, worsted and silk mills. Fig. 5 shows four

motors which form part of a large installation of motor-driven worsted spinning frames. Here the driven shaft speed is relatively low and a Morse silent chain transmits the power from a motor on a bedplate on the floor. The great length of these machines is made evident by this illustration, the power per foot of floor space being relatively small. These motors have an efficiency of about 90 percent and are good illustrations of the latest textile motor practice. Owing to the immense amount of lint and dust in such a room an ordinary ventilated type of motor would not be suc-

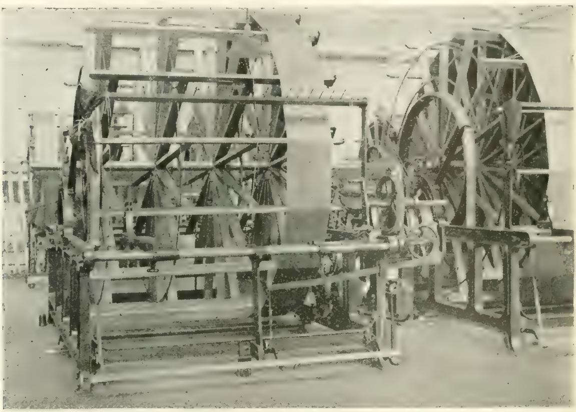


FIG. 8—MOTOR-DRIVEN SILK WARPERS

cessful. There are many variations of this drive, some using gears and others short heavy belts, the belts and chains apparently giving the best results.

The drive for a group of heavy worsted looms comprising part of 180 similar applications is shown in Fig. 6. The advantages of this method for an apparently difficult drive are so great as to make it only necessary to show a sample drive in actual operation to insure an appreciation of its merits. It has been one of the most successful applications yet made, although owing to the bulk and weight of the reciprocating parts it seemed the most unpromising.

Owing to the importance of good speed regulation the loom has presented in all branches of the industry an exceptional opportunity to display the good points of small motor drive. The

silk industry was the first to realize this, partly because a yard of their product was so much more valuable that improvements in weaving were of more importance, and partly because oil drippings from overhead shafting cannot so easily be removed as from cotton or worsted. In any event an immense number of silk mills now consider this the standard drive and will install no other. Motor-operated silk looms are frequently driven through a shock absorbing gear, the motor having a very high starting torque and starting and stopping with the loom. Perhaps a more effective drive still is that shown in Fig. 7, where a high speed motor is

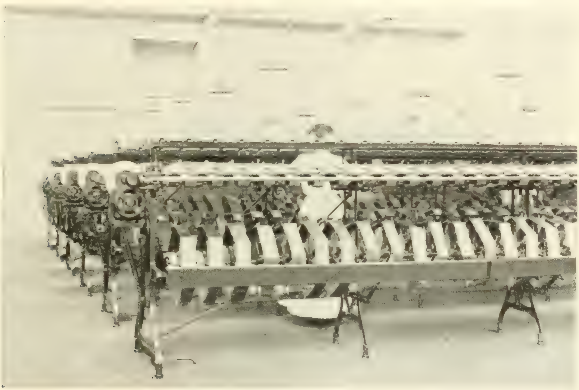


FIG. 9—SILK WINDING MACHINES
Driven by one-half horse-power motors geared to cross shafts.

geared to a large friction clutch which disengages from the loom upon stopping, thus effectually removing all shock from both motor and loom. A textile type switch controlling the motor circuit is simultaneously and automatically opened, so that power consumption stops when the loom ceases operation.

An illustration of motor-driven warpers is given in Fig. 8. Many of the smaller winding machines also are now being motor-driven, Fig. 9 giving an idea of the cleanliness and neatness of a typical installation.

A hydro-extractor or centrifugal drier has always presented one of the most difficult problems for belt or motor drive. The inertia of the basket is very great in proportion to the amount of power required to keep it running after acceleration is complet-

ed. Fig. 10 affords an excellent idea of the most recent development in this field. The use of a motor with a wound secondary and a suitable controller has solved the problem to a nicety. Many of these are being installed in silk and worsted mills where most excellent results are being obtained.

Illustrations of similar drives could be multiplied without number, but enough have been shown to demonstrate the broad field which has already developed. Few textile mill electrifications are now considered without a careful study of the possibilities of individual motor drive, and one cotton mill is now under way in which the largest motor used will be of 20 horse-power capacity. There is scarcely a branch of the textile industry, from the ribbon factories to the heavy carpet mills, which does not present instances of motor drive, and the indications are that the expansion has only started. With the high efficiencies now obtainable in the textile motor all the economies of the old engine drive are equalled, as only the losses in the generator and motors are to be reckoned with. An infinite flexibility and independence is secured, a well-nigh ideal speed regulation, cleanliness, safety, neatness, freedom of light distribution, ease of additional growth and expansion—all these and many more are advantages that are making themselves felt. The time is confidently expected when the use of the individual motor for all the machines of a textile mill will be as standard practice as was the old one thousand horse-power engine of twenty years ago.

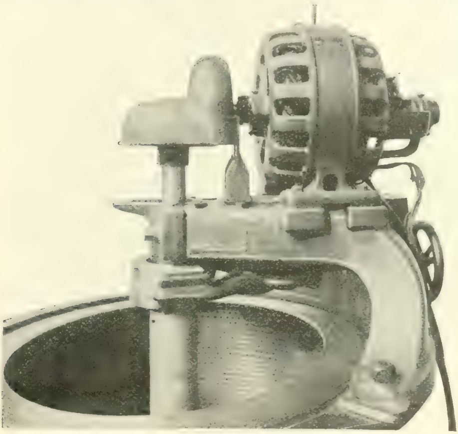


FIG. 10—FORTY-TWO INCH CENTRIFUGAL DRIER
Driven by 7.5 horse-power motor.

SOME STEAM TURBINE CONSIDERATIONS*

EDWIN D. DREYFUS

FROM the standpoint of power production, the present age is veritably a steam turbine era. While the gas engine, hydraulic turbine and reciprocating steam engine may each in turn possess the greater advantage for certain conditions, in the majority of instances present economic considerations dictate the use of the steam turbine for power generation.

The remarkable growth of the turbine industry is particularly noteworthy. With but few exceptions, the turbine has displaced the reciprocating engine in all important steam-electric stations. It is making rapid inroads even in marine work—the stronghold of the reciprocating steam engine—and by reason of the higher efficiencies made possible in marine application by the use of reduction gears, it is safe to predict that the future power in marine vessels will be mainly supplied by turbines. Other developments under way point toward the possible use of reversible and variable speed turbines geared to shafting, in which field the reciprocating engine has been so successfully applied, as well as in condenser and boiler feed service. Compactness and simplicity are the desiderata, and these are the distinguishing features of the turbine.

TABLE I

TURBINE SPEEDS FOR ELECTRIC GENERATORS

Poles	2	4	6	8	10
60 cycle	3600	1800	1200	900	720
25 cycle	1500	750	——	——	——

The intent of this paper is to show some important improvements in construction that have developed in recent years with extended experience. High efficiencies and excellent operating performance have directly followed the introduction of the advanced designs, and these also merit attention.

ROTATIVE SPEEDS

Turbines are essentially high speed machines, the speed of rotation being determined in electric service by the generator. The revolutions per minute which have been used for alternating-current work are shown in Table I.

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*From a paper read before the Engineers' Society of Pennsylvania, Dec. 12, 1910.

Small machines of the reaction type of 550 kw and under have been designed to run at 3 600 r.p.m. for 60 cycles ever since the turbine became a commercial product. Limitations in the electrical art previously confined the rotative speed to within 1 800 r.p.m. for sizes above 500 kw. However, improvements in design

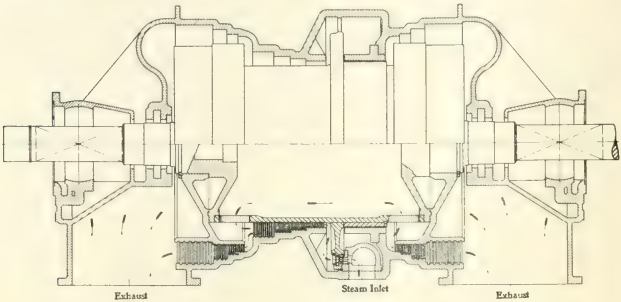


FIG. 1—SEMI-DOUBLE-FLOW TURBINE, 10 000 KW CAPACITY, 750 R.P.M.

and construction now permit the use of higher speeds for the machines of larger capacity. Turbines of 2 500 kw are operating satisfactorily at 3 600 r.p.m., and it is to be expected that 4 000 kw turbines of the same rotative speed will soon be produced.

In the generator the design of the rotor and the character

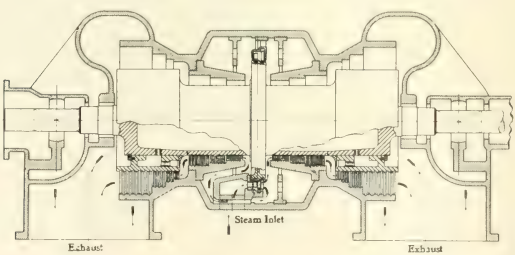


FIG. 2—DOUBLE-FLOW TURBINE, 10 000 KW CAPACITY, 1 800 R.P.M.
Figs. 1 and 2 are reduced to the same relative scale

of the materials have been modified to possess a large factor of safety over and above the centrifugal stresses produced. Generator rotors of the through shaft type have been largely superseded in high speed work by designs having the shaft bolted to the ends of the field disc by means of a non-magnetic coupling in two-pole

machines, and integral with either half of the rotor in four-pole machines, the whole secured by through bolts. In the high speed turbine the problem of mechanical strength is simpler, in a measure, than in the low speed turbine. The maximum blade or peripheral speeds are practically the same in both machines, but naturally with the smaller masses of the higher speed machines, there is more surety of homogeneity of metal, and consequently the rotor of smaller diameter could, if desired, be made to withstand higher strains. The spindle also becomes about 30 percent shorter.

Coincident with the improvement in mechanical construction, a betterment in economy of three to five percent has resulted, due to altered distribution of steam and more favorable blade lengths. A conception of the change in dimensions of the turbine may be obtained by comparing Figs. 1 and 2, which show longitudinal sections of 10 000 kw turbines of 750 and 1 800 r.p.m., respectively,

TABLE II—TEST RESULTS OF 1 000 KW TURBINES AT 1 800 AND 3600 R.P.M.

150 lbs. gauge, 100 degrees F. superheat and 28 in. vacuum (30 in. bar).

Date of Test	Feb. '07	Jan. '07	Avg.	Aug. '09	Aug. '09	Avg.	Percent Improvement
R.P.M.	1800	1800	——	3600	3600	——	
Half Load	20.4	19.93	20.17	19.58	19.00	19.29	4.4
Full Load	17.15	17.50	17.33	16.79	16.30	16.55	4.5

reduced to the same relative scale. An example of the improvement in efficiency actually accomplished is furnished by tests of four 1 000 kw turbines for the United States Navy Yards, authenticated by a government representative. In Table II are included the final results obtained with two machines of 1 800 and two of 3 600 r.p.m., respectively. The gain, both in regard to dimensions and efficiencies, applies to larger units as well as to the 1 000 kw machines compared.

Modern rotor constructions are shown in Figs. 3, 4 and 5,

The improvements in the general design of the turbine have kept pace with those of the spindle already noted. In the early machines the cylinders were made with rib and web reinforce-types, enhancing as it does the mechanical merits of the machines.

CONSTRUCTION

giving the high speed single-flow spindle, the semi-double-flow and the straight double-flow Parsons designs. These views evidence the marked uniformity of section obtaining in the latest high speed

ments and with equalizer passages and turbine supports cast as an integral part of the casing. Material of different thicknesses at certain parts, and the varying temperature occurring in the tur-

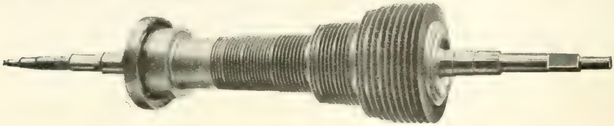


FIG. 3—SINGLE-FLOW SPINDLE

bine did not encourage uniformity of cylinder expansion nor facilitate the production of the casting. Such features were mainly accountable for the troubles at first experienced. The early designs were constantly improved until the construction shown in

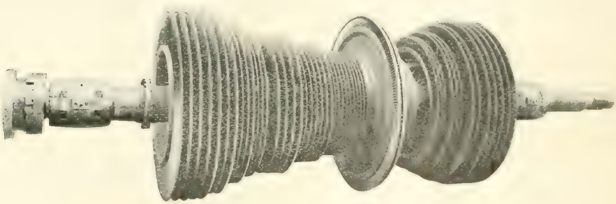


FIG. 4—SEMI-DOUBLE-FLOW SPINDLE

Fig. 6 was developed within the past two years. The excellence of the arrangement is quite obvious in that the cylinder cover and base are entirely symmetrical and not encumbered by external ports. Furthermore, independent supports are provided for the exhaust passages, permitting them to expand and contract freely without

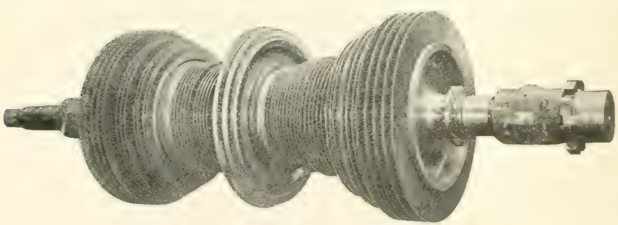


FIG. 5—DOUBLE-FLOW SPINDLE

disturbing the alignment. The important features are shown in the illustration, Fig. 7, of two 1 000 kw units at the Dartmouth Manufacturing Company, Dartmouth, Mass. These machines are

equipped with combined automatic throttle and globe valves which insure that the automatic stop is in good operating condition at all times, as the various valve parts must be capable of performing their respective functions before the machine can be started. A tachometer is provided (visible in Fig. 7 at the end of the shaft) which serves as a useful indicator in starting up and shutting down.

The preceding discussion applies especially to the smaller sizes. When large capacities are encountered a different problem arises. The size of the exhaust port becomes disproportionately large as compared with the turbine cylinder, necessitating a casting that is

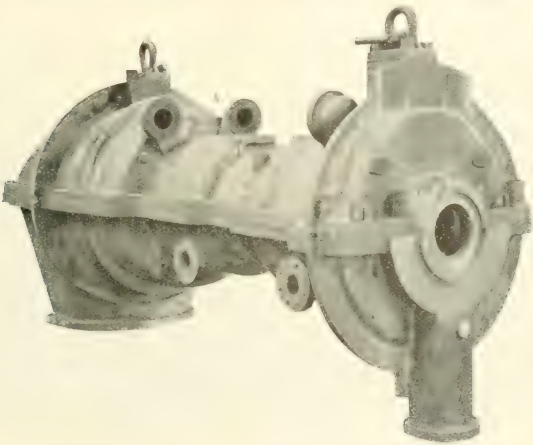


FIG. 6—IMPROVED SINGLE-FLOW CYLINDER CONSTRUCTION

difficult to make, and naturally a division of the large volume of steam at the low pressure end suggested itself to the designer.

In these large machines the distance between bearings is another item that the designer must contend with in dealing with bending moments and stresses. It would be impractical to place two reaction machines end to end and divide the flow in opposite directions through the two smaller elements. One of the solutions, then, was to substitute for the longest and least efficient section of such a combined machine a short impulse wheel of about equal efficiency. In doing this, the unit was shortened by over 30 percent as compared with the single-flow design. Another advantage secured for large turbines is the elimination of two of the dummy pistons of

the reaction type turbine, as the two low pressure sections equalize their end thrust, and the impulse section, with all of the expansion taking place in the nozzles, requires no counterbalancing. For the low speeds obtaining in 25 cycle work, the intermediate stage is retained as a single-flow element in order to provide the best blade lengths. A representative section of this type of machine is given in Fig. 1. A feature of interest is the scheme employed to divide the steam between the two equal low pressure stages at opposite ends of the spindle. To pass this large volume of steam through external passages would have required cumbersome ports secured to the cylinder. This was ingeniously avoided by arranging steam passages in the rotor so that the steam to the low pressure blading would conveniently flow as indicated by the arrows.

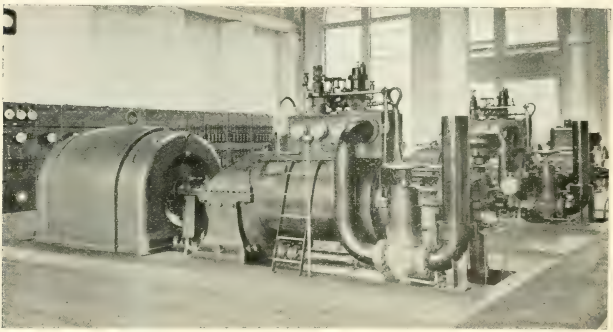


FIG. 7—TWO 1 000 KW SINGLE-FLOW STEAM TURBINE GENERATOR UNITS, 3 600 R. P. M.
Dartmouth Manufacturing Corporation, Dartmouth, Mass.

As previously indicated, developments in the art have permitted the use of higher rotative speeds and consequently more efficient blading. Therefore, for such speeds as are employed in 60 cycle work, a straight double-flow design lends itself admirably. These improvements have resulted in a turbine of the type shown in section in Fig. 2, which affords an exceptionally symmetrical structure. The subdivision of the steam, which is of relatively small volume after it issues from the impulse wheels, is very simply accomplished by means of a short passage around the nozzle blocks. An exterior view of a double-flow turbine is presented in Fig. 8.

This composite, or hybrid design was first conceived in this country. It is now rapidly growing to be a leading type here,

while abroad it is also gaining favor in a very marked manner. The general results of nozzle and blade experiments range from 95 to 98 percent efficiency, while that of single buckets may vary from 70 to 85 percent. While this salient fact has not been sufficiently regarded in the past, it was pertinently considered in an engineering paper by Mr. C. H. Smoot, before the National Electric Light Association, June, 1909, and the disadvantage of several velocity drops, using a number of buckets in series for absorbing the energy of a large expansion range, was manifested. Reaction turbines have specially constructed blade formation which provides the same results as nozzles, i. e., expansion takes place in both the rotating and

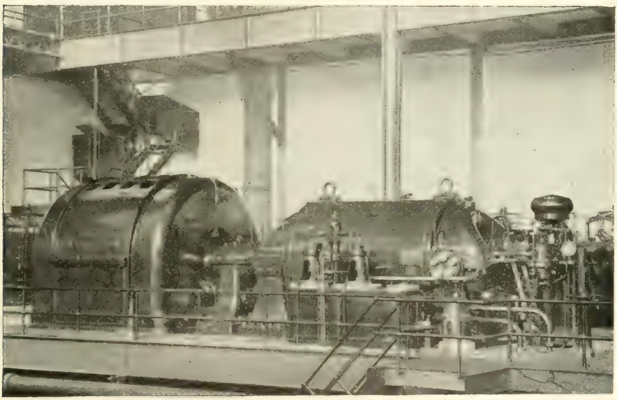


FIG. 8—10 000 K.V.A. DOUBLE-FLOW TURBINE AND GENERATOR, 1 800 R.P.M.
Metropolitan Street Railway Company, Kansas City, Mo.

stationary elements. In the impulse type the area of the steam passage through the buckets is practically constant. With reaction blades varying cross-section of the steam passages is established in precisely the same manner as with nozzles. This feature is illustrated in the upper part of Fig. 9, and is a contributing factor in the high efficiency records attained with the reaction steam turbine. Only when these blades are of relatively short lengths do they become of uneconomical proportion with respect to the leakage annulus. The blades are shortest in the high pressure stage, and, therefore, the use of the impulse wheel in this part of the turbine does not detract from the efficiency. Moreover, the use of the impulse section, utilizing a high pressure and high heat drop, re-

moves the wide difference of temperature and pressure within the cylinder, which grows in importance with large units.

The difference between the two types of blading which have been placed in the one machine will be directly observed, as the impulse buckets are of much heavier section by reason of the higher velocities involved, necessitating a wider face and greater depth of blade. A shroud is required to maintain the steam in the blade passage, which in the reaction blading is neither necessary nor desirable, inasmuch as it would not serve a similar function. Owing to the heavier section of the impulse blades, and due to the fact that they usually run at higher speeds, greater provision must be made for safely securing them to the rotor. Evidently, there exists little if any difference in the mechanical integrity of the two types; in fact, the conservatism is probably greater in the reaction blading. Extensive records prove an equal element of safety in operation, notwithstanding the prejudiced criticisms of the small radial clearances employed. It is to be remembered that such clearances allow amply for all distortion which may bring the spindle and cylinder in contact, and more liberality in design is unwarranted.

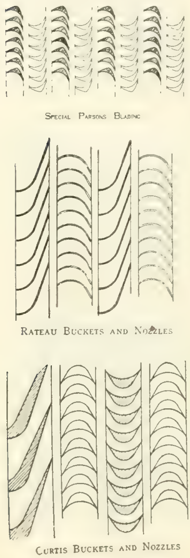


FIG. 9—TYPICAL NOZZLE AND BLADE CONSTRUCTION
Upper view, reaction blading; lower views, impulse nozzles and buckets

APPLICATION

The turbine was for many years confined entirely to direct driving of generators, but has recently come into favor for boiler feed, exciter and condenser service. The same considerations which have governed the selection of turbines for main units apply with equal force to the selection of exciter sets, and, inasmuch as the installation of steam driven auxiliaries has been found to be most economical in the majority of power plants, this type of machine is being installed with greater frequency. The general compactness of a turbine driven exciter is illustrated in Fig. 10, which shows an arrangement occupy-

ing the minimum of floor space. Similar units have been installed for isolated plants and also for train lighting.

In the trend toward the displacement of reciprocating machinery by the rotative type, a unique and important condenser has been devised with auxiliaries of the rotating type which accommodate themselves to turbine drive by virtue of their operating speeds. This type of condenser is manufactured under the Leblanc patents which relate to the removal of air from the condenser body or chamber by sheets of water projected from the air pump runner. This construction* possesses many advantages other than the par-

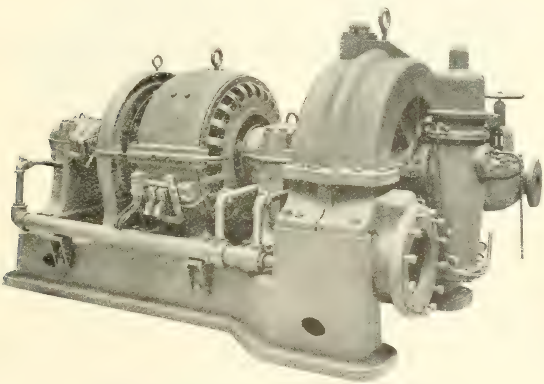


FIG. 10—150 KW TURBINE-DRIVEN EXCITER

ticular point mentioned in this connection; i. e., that it advantageously employs turbine drive.

To complete the station equipment with all turbine driven apparatus, it is only necessary to provide boiler feed pumps of this class. With the better knowledge of the theory of centrifugal pumps, and with more skill in their design, it has become feasible to furnish boiler feeders of the type shown in Fig. 11, to deliver against 200 to 300 lbs. pressure. This boiler feed pump is of the three stage type, running at 650 r.p.m. and delivering 500 gallons per minute against 200 lbs. pressure per sq. in. It requires a turbine of 110 hp which is designed to operate at 165 lbs. boiler pres-

*See article on the Leblanc Condenser by Mr. R. N. Ehrhart, in the JOURNAL for July, 1910, p. 526.

sure and exhaust against atmospheric pressure. It is safe to predict that within a short time the use of the turbine will be further extended by the recent advent of a practical reduction gear, the invention of Melville and Macalpine.* The high speed turbine with this reduction gear has made its entry into marine service, and it is reasonable to expect that in the near future it will be the principal motive power on marine vessels. This particular reduction

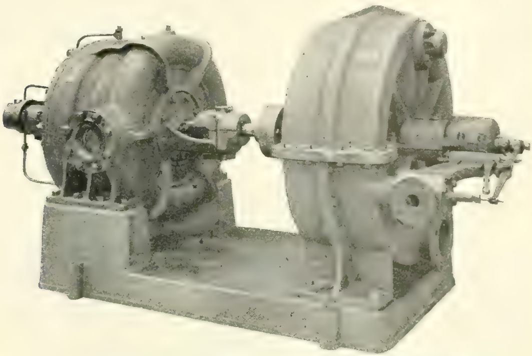


FIG. 11—TURBINE-DRIVEN BOILER FEED PUMP
Rating, 110 hp at 165 lbs. boiler pressure; 650 r.p.m.
Pumps 500 gal. per min. against 200 lbs. pressure.

gear also permits the best selection of turbine and direct-current generator speeds for the most satisfactory performance and best efficiencies in both elements.

(To be continued.)

*See article, "Broadening the Field of the Marine Steam Turbine," by Mr. George Westinghouse in the JOURNAL for January, 1910.

WEIGHT TRANSFER IN ELECTRIC CARS AND LOCOMOTIVES

G. M. EATON

WHEN the axles of an electric locomotive or car are independently driven, that is, when each axle is driven by its own motor, it is well recognized that under maximum tractive effort conditions the wheels on certain of the axles will slip on the rails in advance of the other wheels. The fundamental principles acting to produce this result, however, are not so generally understood and a brief explanation will show the importance of giving due consideration to this as a feature of design in order to obtain maximum adhesion and reduce the liability of slipping of the wheels.

The simplest case may be illustrated by a mine haulage locomotive in Fig. 1. Assume that the locomotive is standing still and is

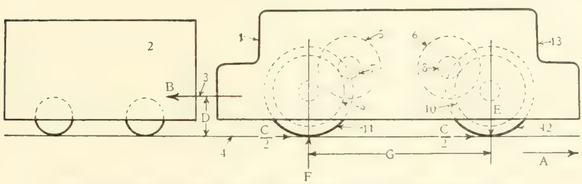


FIG. 1—MINE HAULAGE LOCOMOTIVE EXERTING DRAW-BAR PULL AT STANDSTILL

1—locomotive; *2*—trailing load; *3*—draw bar; *4*—top of the running rail; *5* and *6*—the driving motors; *7* and *8*—pinions on the end of the armature shafts, engaging with *9* and *10* which are gears mounted on the axles; *11* and *12*—pairs of driving wheels; *13*—body or frame work of the locomotive.

exerting its maximum draw bar pull in the direction *A*. The draw bar pull, as it is applied to the locomotive, may be represented in location and direction by *B*. The wheels are then exerting an equal force at the rails and the rail reaction on the locomotive is represented by $C = C/2 + C/2$ which, under the conditions noted, is equal to *B*. It should be noted that *B* is less than the tractive effort of the motors by the amount necessary to overcome the static internal friction of the locomotive. The two forces *B* and *C* then constitute a couple which is tending to produce an anti-clockwise rotation of the entire locomotive. To maintain equilibrium there must be an equivalent couple tending to produce an opposite rotation of

the entire locomotive. It is evident that the only points where such a couple can exist are the points of contact between the wheels and rails and the forces are represented by *E* and *F* which are equal. That is to say, a part of the weight on the wheels *12* is being used to maintain equilibrium and is not available for adhesion, while the rails are exerting on the wheels *11* a force in addition to their normal share of weight and this force as well as the weight is available for adhesion. If *W* is the weight of the locomotive and if in repose this weight is equally divided between the two axles, it will be seen that under maximum tractive conditions the rail pressure on the wheels *11* equals $\frac{W}{2} + F$ and on the wheels *12* equals $\frac{W}{2} - E$. The value of *E* and *F* may be determined from the equation of equilibrium $B \times D = E \times G$ or $E = \frac{B \times D}{G}$ where *D* is the distance of the line of application of the draw bar

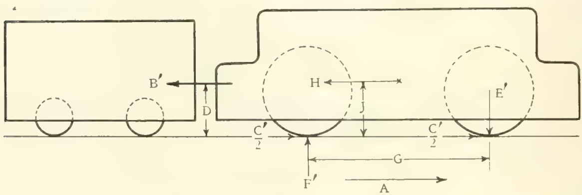


FIG. 2—MINE HAULAGE LOCOMOTIVE
Accelerating.

pull above the rails and *G* is the wheel base of the locomotive. The expression $E \times G$ will be referred to as the transfer couple. Then with an equal coefficient of friction between the rail and each set of wheels it is evident that if the motors 5 and *6* are taking an equal current the wheels *12* will be the first to slip.

It will be noted that in this discussion no attention has been given to the method of mounting the motors. Given a constant weight distribution in repose on the two axles with various motor arrangements, it makes no difference where the motors are hung or how they connect to their axles, except that the connection must be such as to produce an equal pull at the wheel tread with equal current in the motors. The only factors necessary in determining the value of *E* or *F,* termed the weight transfer, are the draw bar pull, the height of the draw bar above the rail and the wheel base. This is because the draw bar and the wheel contacts with the rails

are the only points at which external disturbing forces acting upon the entire locomotive can be applied. Such factors as gear tooth pressure, axle bearing pressures, etc., are strictly internal forces producing internal stresses in the locomotive framing, etc., but having no effect upon the equilibrium of the locomotive as a whole. They are, in other words, "boot strap" forces.

If the locomotive service is such that the maximum draw bar pull is demanded in only one direction it is evident that the most advantageous use of the adhesion can be obtained by making the normal or repose weight on the wheels *12* equal to $\frac{W}{2} + E$ and upon the wheels *11* equal to $\frac{W}{2} - F$. Then under the maximum tractive conditions, each pair of wheels would have a weight of $\frac{W}{2}$ available for adhesion and theoretically both wheels would slip at the same

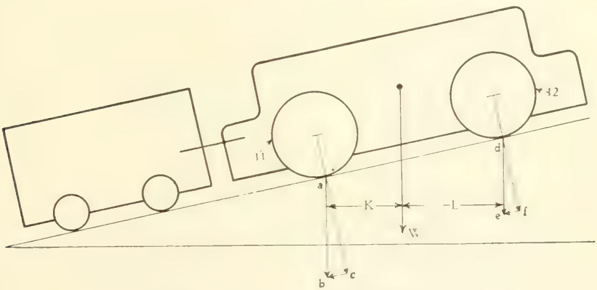


FIG. 3—MINE HAULAGE LOCOMOTIVE
Standing on grade.

instant. When, however, as is usually the case, the maximum effort is demanded in both directions it is evident that this arrangement would be unsatisfactory.

A very easy way of making use of the total adhesion at all times is to connect the two axles by quartered side rods as in a steam locomotive, and mining locomotives and electric cars have been built embodying this principle. The two motors and the two axles then become a rotative unit and individual slippage can not occur. Another method of preventing the wheels *12* from slipping prematurely would be to reduce the percentage current passing through the motor *6*, and this has been done on some experimental

locomotives. It has proven, however, to be an unjustifiable complication.

When the locomotive is accelerating, the conditions are somewhat different. The forces acting under these conditions are indicated in Fig. 2. Assuming the tractive effort of the motors to be the same as before, it will be noted that the rail reaction upon the wheels, viz., C', is less than C in Fig. 1, due to the fact that the tractive effort of the motors is partly expended in producing accelerated rotation of the armatures, gears, wheels, etc., and in overcoming the total running friction of the locomotive. If it is assumed that one half of the energy used in producing accelerated rotation is ex-

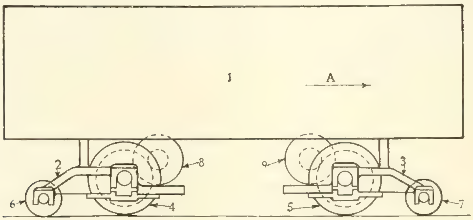


FIG. 4—OUTLINE OF MAXIMUM TRACTION CAR SHOWING HOW SLIPPING OF DRIVING WHEELS OCCURS

1—Car body; *2* and *3*—truck frames; *4* and *5*—pairs of driving wheels; *6* and *7*—pairs of idle leading and trailing wheels; *8* and *9*—driving motors, hung outside of the truck wheel base for the double purpose of securing a short truck wheel base and to throw a larger share of the weight upon the driving wheels *4* and *5* than upon the idle wheels *6* and *7*. The gears and pinions are as outlined under Fig. 1.

pended on the armature and that the other half is absorbed by the gear and wheels, then the forces producing this accelerated rotation will produce no weight transfer. In the case of gearless motors a slight weight transfer is produced by the forces which cause accelerated rotation, but as the transfer is comparatively small, it will not be of particular interest to outline the method of computation. (It should be noted that the relative effects of the internal friction of the locomotive under the static conditions of Fig. 1 and the accelerating condition of Fig. 2 have been omitted from the discussion.)

The tractive effort of the motors during acceleration is further expended in overcoming the inertia of advance of the entire locomotive. The force exerted by the inertia of advance is repre-

sented by H, Fig. 2, which acts at the center of gravity of the entire locomotive. The draw bar pull B' is then the remainder of the tractive effort. The equation of equilibrium of advance is $C' = B' + H$ and the equation of equilibrium of rotation of the entire locomotive is $E' \times G = B' \times D + H \times J$. The expression $H \times J$ will be referred to as the inertia couple.

When the locomotive is on a grade as in Fig. 3 there is a weight transfer to the down hill wheels due to the grade itself, the weight W being divided upon the wheels *11* and *12* in the ratio of L to K; however, under conditions practicable for adhesive operation this transfer is very small. For instance, the transfer due to a ten percent grade with a locomotive of the type shown in Fig. 3, whose center of gravity is distant from the rail by an amount

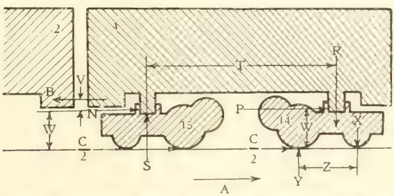


FIG. 5—DIAGRAM OF MAXIMUM TRACTION CAR EXERTING DRAW-BAR PULL AT STANDSTILL

equal to say one-fourth of the rigid wheel base, would be approximately 2.5 percent of the total locomotive weight.

When running up a grade the rail reaction upon the wheels must not only overcome the entire running friction of the locomotive and the inertia for any acceleration, but it must also actually lift the locomotive up the grade. The force expended in lifting the locomotive itself constitutes a loss of draw bar pull and this force produces no weight transfer. To prove this fact, consider the locomotive as a single unit of mass, standing at rest on the grade. The weight supported on the wheels *11* in Fig 3 may be represented by $ab = L$, and the weight on the wheels *12* by $de = K$. Draw ac and df perpendicular to the rails and draw bc and ef parallel to the rails. Then ac and df represent the normal pressure on the rails, and bc and ef represent the reactions parallel to the rails "exerted at the points of wheel and rail contact" to the forces which hold the locomotive from running down the grade,

or to lift it up the grade. Since these reactions are exerted at the rail they can form no couple, as they are directly opposed to the forces which the rails exert on the wheels. Therefore, as stated, the forces which lift the locomotive up the grade produce no weight transfer.

If there is acceleration the analysis is the same as under Fig. 2. The method of calculating the weight transfer due to the tractive effort under the conditions of Fig. 3 is therefore the same as

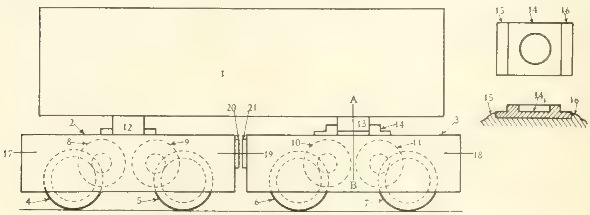


FIG. 6—ARTICULATED TRUCK LOCOMOTIVE IN WHICH TRACTIVE EFFORT IS TRANSMITTED THROUGH TRUCK FRAMES

1—Cab; *2* and *3*—truck frames; *4*, *5*, *6* and *7*—pairs of driving wheels; *8*, *9*, *10* and *11*—motors; *12*—a center pin of the usual type; *13*—a center pin arranged so that instead of mating with an integral part of the truck frame it engages with *14*, which is a shoe arranged to slip longitudinally relative to the truck frame *3*, but restrained transversely by *15* and *16* which are guides forming an integral part of *3*; *17* and *18*—couplers carried directly on the truck frame; *19*—a heavy link pinned at its ends to the truck from *2* and *3*, preferably at the same height above the rail as the couplers; this link is made with a slotted hole for the pin at one end so that it can act as a draw bar between the two trucks but cannot be subjected to heavy compression resulting from bumping actions; *20* and *21*—solid buffers which receive the bumping strains.

that outlined under Figs. 1 and 2, except that the draw bar pull is decreased by the amount necessary to lift the locomotive, viz., 20 pounds per ton (2 000 lbs.) of locomotive weight for each percent of grade.

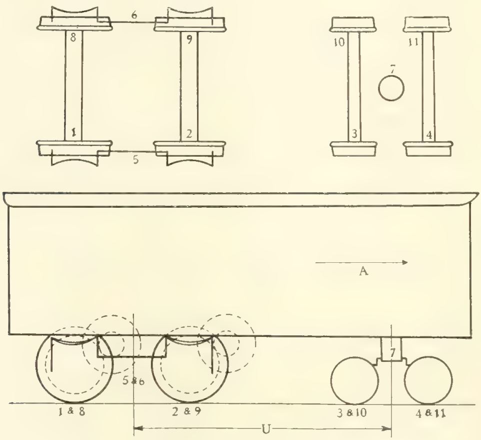
Street cars equipped with maximum traction trucks give a very practical illustration of the slipping of individual pairs of wheels. A car of this description is outlined in Fig. 4. No exact details of motor mounting are given because, as before stated, such details

have no bearing upon the immediate discussion. To reduce the problem to its fundamental elements the discussion will be based on Fig. 5. In order to parallel the discussion under Fig. 1, assume that the motor car *1* is coupled to the trailer *2* and is exerting its maximum tractive effort at a standstill. The draw bar reaction on the motor car body is then represented by *B,* while *X* and P represent the center pin pull exerted upon the car body. Equilibrium of advance is expressed by the equation $B = X + P$, *X* and *P* being equal. If, as indicated, the draw bar and the center pins are not at the same level there will be a transfer of weight from the truck *14* to the truck *15* represented by *R* and *S*. The value of the transfer is derived from the equation $B \times V = R \times T$ or $R = \frac{B \times V}{T}$ where *T* is the truck center distance. This value will usually be so small as to be negligible; *R* and *S* are equal as before. In each truck there is a transfer of weight from the leading to the trailing axle, the transfer being of the same value for each truck. In the arrangement indicated, however, it will be seen that the weight on the driving axle of the leading truck *11* is increased, while that on the driving axle of the trailing truck is decreased. It will be noted that $P = \frac{C}{2}$ The value of the transfer is derived from the equation $P \times W = Y \times Z$ or $Y = \frac{P \times W}{Z}$, *X* and *Y* being equal as before. It is then evident that under the assumed conditions the driving axle of the truck *15* will be the first to slip as the weight transfer *R* can not entirely offset *Y* and in fact in some cases, (viz., where *B* is applied nearer to the rail than *X* and *P*) acts in conjunction with *Y* to hasten the slipping of the rear truck driving axle. The remedy is apparent, if the car is designed for operation in direction *A* only. Under such conditions the driving and idle axles of the truck *15* should be interchanged. The only weight transfer then tending to produce premature slipping is *R* which, as stated, is practically negligible. Again, however, it is evident that for double ended operation demanding maximum traction in both directions this would not be an operative arrangement.

In view of the discussion under Fig. 2 it will be sufficiently clear to state without further illustrations that under accelerating conditions with a car arranged as in Fig. 5 there will be a weight transfer to the center pin of the truck *15* due to the inertia of the car body acting at its center of gravity. The arm of the inertia

couple will be the vertical distance from the center pin to this center of gravity. There will also be in each truck a transfer of weight due to the inertia of the truck itself, which may be analyzed as outlined under Fig. 2.

In double truck locomotives designed for heavy pulling, the weight transfer can be reduced by transmitting the tractive effort directly through the truck frames instead of through the center pins and cab. Fig. 6 shows a locomotive of this description, this type being usually termed an "articulated truck locomotive." Under static



FIGS. 7 AND 8—AMERICAN TYPE LOCOMOTIVE
Showing relation of equalization to weight transfer.

pulling conditions each truck is subjected to the weight transfer due to the draw bar pull developed by its own motors, the pull of the leading truck, when the articulation link is at the same height as the couplers, being transmitted directly through the framing of the trailing truck without producing in it any additional weight transfer. The transfer produced is less than that existing when the couplers are mounted on the cab, because in heavy locomotives it is seldom or never practicable (for structural reasons) to locate the center pin as close to the rail as the standard M.C.B. coupler height. Under accelerating conditions the weight transfer due to inertia

can be derived by the methods outlined under Fig. 5.

In the more complicated wheel arrangements existing in many locomotives the same general principles apply. There is one additional feature, however, which must be taken into consideration, viz., the equalizing system. Instead of taking the distance between the axles that may be under consideration as the arm of the transfer couple it is necessary to employ the distance between the centers of the equalization. This is outlined in Figs. 7 and 8.* The wheels *1* and *2* are equalized together as are also the wheels *8* and *9*. The weight of the locomotive body is applied to the truck at the center pin and the truck is so constructed that an equal weight is carried by each of the wheels *3*, *4*, *10* and *11*. In this case the centers of equalization are *5*, *6* and *7*, and the arm of the transfer couple is *U*. In the case illustrated in Figs. 7 and 8 with advance in the direction *A*, an equal amount of weight is removed from each of the wheels of the leading truck and a like amount is added to each of the drivers.

It is entirely possible to reach the results derived by the methods outlined in the preceding discussion by an analysis of all of the internal forces exerted by the various elements of a particular machine that may be under investigation. Such an analysis is essential for a proper proportioning of the various details of the structure. The analysis is, however, rather complicated with corresponding liability for error and it is always advisable to check the accuracy of the results thus obtained by the sole consideration of external forces.

*The principles of equalization are outlined in an article in the JOURNAL for December, 1910, p. 943, reference to which will assist in an understanding of the present discussion if these principles are unfamiliar.

ELECTROSTATIC STRESSES AND GROUND CONNECTIONS

THEIR EFFECT ON INSULATION OF TRANSFORMER SECONDARY WINDINGS

C. FORTESCUE

[This is the seventh of the series of articles on the general subject of continuity of service in transmission systems dealing particularly with static stresses and line troubles, and the proper protection of transmission systems from such troubles.]

A GROUND on the transmission line gives rise to two conditions of stress in the transformers, viz., the initial or tranient condition, and the final or steady condition. The initial condition is caused by the surges resulting from the sudden change in the charging currents on the transmission system, which create a high potential difference between the end turns of the transformers. The final or steady condition of stress depends on the electrostatic capacity between the high and low-tension windings, and the electrostatic capacity between the low-tension windings and ground. The subject is of importance, since failure of the insulation may cause interruption of service and, in certain cases, the more serious question of personal safety may be involved.

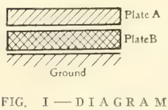


FIG. 1—DIAGRAM REPRESENTING STATIC POTENTIAL RELATIONS BETWEEN HIGH AND LOW-TENSION WINDINGS AND THE IRON OF A TRANSFORMER

In this article particular attention will be given to the latter condition. It will be shown how the stresses of this nature, occurring under various conditions of operation, may be calculated. The simplest case will be considered first, viz., that of a single-phase transformer operating on a single-phase circuit.

The relations between the high and low-tension windings and the iron of a transformer are analogous to those between the system of parallel plate condensers illustrated in Fig. 1. For example, if the capacity between plate A and plate B is equal to that between plate B and ground, and if plate A be maintained at potential V above ground, the potential of plate B will be $V \div 2$. Again, if the capacity between plates A and B be one-half that between B and ground, the potential of plate B will be $V \div 3$. Finally, if the capacity between A and B be $(1 \div n)$ times that between B and ground, the potential of plate B will be $V \div (n + 1)$. Fig. 2 shows the cross-section of a very simple type of transformer. The low-tension coils AA' are in series; likewise the high-tension coil BB'.

The direction and relative intensity of the charging currents from high-tension to low-tension windings and from low-tension winding to ground is shown by the direction of the arrows and their relative density. The following rule has been deduced by simple mathematical analysis, for a symmetrically designed single-phase transformer operating on a single-phase circuit:—

> The potential above ground of the middle point of the low-tension winding is equal to the potential above ground of the middle point of the high-tension winding multiplied by the ratio of the capacity between the high and low-tension windings to the sum of the capacities between high and low-tension windings and between low-tension winding and ground.

The stresses between the adjacent high and low-tension coils of a transformer depend upon its polarity. The following are definitions of what will be termed in this article "positive" and "negative" polarity of transformers:—

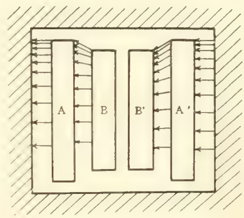


FIG. 2—CROSS SECTION OF SIMPLE TRANSFORMER, SHOWING DIRECTION AND RELATIVE INTENSITY OF INSTANTANEOUS CHARGING CURRENTS FROM WINDINGS TO GROUND AND VICE VERSA

The polarity of a transformer is positive when, on connecting the adjacent ends of the high and low-tension windings (i. e., the terminals from *A* and *B* in Fig. 2) and impressing an e.m.f. on the high-tension winding, the e.m.f. between the remaining ends of the high and low-tension windings is equal to the sum of the impressed e.m.f. and the low-tenion e.m.f.

Conversely, the polarity is negative when the resultant e.m.f. is the difference instead of the sum.

Polarity, in the sense here employed, depends upon the internal windings and connections, and not upon the external connections. The internal polarity is determined by the relative direction of the windings as shown in Fig. 3 and also by the order in which the coils are connected. Beginning at the adjacent ends of the primary and secondary windings, the coils may be wound in the same direction around the core or they may be wound in opposite directions. Again, if the transformer windings each contain a considerable number of coils which are interlaced, the coils in either winding may be connected in series directly, or the terminals of each may be reversed before they are connected in series.

The reversing of the individual coils in this way changes the polarity from one sense to the other. In some cases the electrical connection is not in the order of their mechanical position which leads to a more complex case, which is not here considered.

In calculating the capacities for the application of the rule given above, it will usually be sufficiently accurate to consider the adjacent high and low-tension coils as parallel plates and take as the total capacity the sum of the capacities found in this manner. Let the capacities between high and low-tension windings, and low-tension windings and ground, be denoted respectively by C_1 and C_2; let the ends of the high-tension winding be denoted by A and B, and the ends of the low-tension windings by C and D, so that A and C

TABLE I—EFFECT OF AN ACCIDENTAL GROUND ON TRANSFORMER POTENTIAL STRESSES

Normal Operation	Polarity of Transformers	
	Positive	Negative
Maximum value of high-tension potential above ground	33000	33000
Maximum value of low-tension potential above ground	3300	3300
Maximum difference between adjacent coils of high and low tension windings	36300	29700
One Terminal Grounded*		
Potential of B	0	0
Potential of A	66000	66000
Potential of middle point of high-tension winding	33000	33000
Potential of middle point of low-tension winding	16500	16500
Potential of C . . (16500 ∓ 3300)	13200	19800
Potential of D . . (16500 ± 3300)	19800	13200
Potential difference between B and D	19800	13200
Potential difference between A and C	52800	46200

*It is assumed in calculating these values that C_1 C_2, a reasonable assumption to make.

are the ends of adjacent coils or groups and B and D are ends of adjacent coils or groups at the opposite ends of both windings. Assuming, then, that a 66 000/6 600 volt transformer is operating from a 66 000 volt, single-phase line and that the low-tension circuit breakers are open; the potential values in volts that will be obtained at various points of the transformer, under normal operating conditions* and with one terminal accidentally grounded, are given in Table I.

It will be apparent from the above that there are possibilities of extremely high electrical stresses in the insulation of a trans-

*By operation "under normal conditions" is meant operation on a perfectly symmetrical system with an approximately balanced load. This is a reasonable assumption for the great majority of transmission systems.

former when one end becomes grounded. Fortunately for the insulation of the low-tension winding, apparatus connected to the circuit increases the electrostatic capacity of the low-tension winding to ground so that as long as there is a connected load the stresses do not reach very high values; however, should the low-tension circuit breakers open while there is a grounded high-tension line, the stresses set up in the transformer insulation might lead to serious trouble.

Another point worthy of note is the effect of the relative direction of the high and low-tension windings, that is, the polarity of the transformers, on the stresses betwen the high and low-tension windings. It will be seen that these stresses are considerably higher for the transformer of positive polarity that for the one of negative polarity, under all conditions of operation. It would be reasonable to require a correspondingly higher test voltage to be applied on the insulation between the high and low-tension windings for transformers of positive polarity.

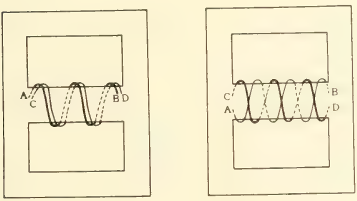


FIG. 3—SIMPLE TRANSFORMER SHOWING METHODS OF WINDING THE PRIMARY AND SECONDARY COILS IN ORDER TO OBTAIN INTERNALLY "POSITIVE" POLARITY AND "NEGATIVE" POLARITY

If one of the high-tension lines breaks, both ends usually go to ground, but there is a possibility of one end remaining ungrounded. Under this condition the transformers at the ungrounded end of the transmission line will have their high-tension windings raised to full line potential above ground, this being also, approximately, the potential of the middle point. The high-tension and low-tension e.m.f.'s are zero, but the low-tension winding will be raised to a potential above ground equal to $Vp\ C_1 \div (C_1 + C_2)$, approximately, provided that there is no connected load on the low-tension circuit, Vp representing line potential, and C_1 and C_2 the values previously given.

The remedy for these troubles is simple. It consists in grounding the middle point of either the high or low-tension windings. If the first method is used, the circuit breakers open when the high-tension line goes to ground and the insulation stress between the low-tension winding and ground cannot exceed the low-tension

e.m.f. The second method will increase the stress between high and low-tension windings, but this can be provided for. If both windings are grounded at this middle point, when a line becomes grounded the breakers open and thus no part of the transformer is subjected to a steady stress above that occurring under normal operation.

There have been various schemes used to overcome this trouble without the necessity of grounding the low-tension circuit; the ground shield is perhaps the oldest of these. It consists of a grounded conductor interposed between the high and low-tension windings, thereby reducing the capacity between them to zero. The middle point of the low-tension winding will therefore always be at zero potential for any distribution, independent of the potential in the high-tension winding. The great objection to the ground

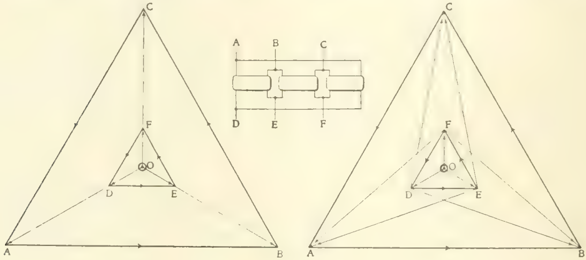


FIG. 4 FIG. 5

POTENTIAL DIAGRAMS FOR DELTA-DELTA CONNECTED GROUPS OF TRANSFORMERS OPERATING UNDER NORMAL CONDITIONS ON A THREE-PHASE CIRCUIT. FIG. 4 APPLIES TO TRANSFORMERS OF NEGATIVE POLARITY AND FIG. 5 TO TRANSFORMERS OF POSITIVE POLARITY

The point *O*, at zero potential, is the centroid of the two e.m.f. triangles. Thus, *O* represents the point of mean potential of the high and low-tension windings.

shield is on account of the increased intensity of the stresses on the insulation at its edges under normal operating conditions. This necessitates more insulation than would be required to protect the same transformer operating with the middle of the low-tension winding grounded and affords no better protection.

In the design of transformers to be operated with ungrounded circuits, the capacity between low-tension winding and ground should be made as high as possible; there should also be ample insulation between the high and low-tension windings. Since the induced potential in the low-tension winding extends to the rest of

the circuit, and, since this stress increases as the distance between the low-tension windings and the iron becomes greater, the insulation from the low-tension winding to ground should preferably not be required to stand a very much higher test than other apparatus on the same circuit, unless this higher insulation strength can be attained without reducing the capacity between the low-tension winding and ground.

In discussing polyphase systems frequent use will be made of what will be termed the "potential diagram". If a point be taken as the point of zero potential, the potentials of any polyphase system may be represented by other points on the same plane, if the potentials are simple periodic quantities. The distance of any one of these points from the zero will give the maximum or effective

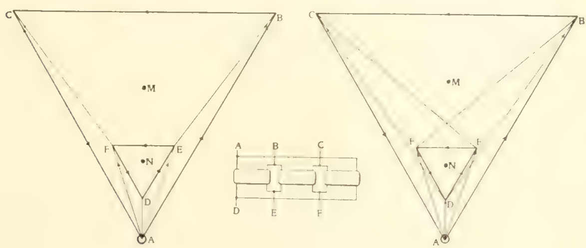


FIG. 6 FIG. 7

POTENTIAL DIAGRAMS FOR DELTA-DELTA CONNECTED GROUPS OF TRANSFORMERS OPERATING ON A THREE-PHASE CIRCUIT WITH ONE LINE GROUNDED. FIG. 6 APPLIES TO TRANSFORMERS OF NEGATIVE, AND FIG. 7 TO TRANSFORMERS OF POSITIVE POLARITY

A is at zero potential. In these and the following diagrams M is the point of mean potential of the high-tension windings and N that of the low-tension windings.

value of the potential of the corresponding point of the system, and the line drawn between any two points will represent in magnitude and direction the e.m.f. or difference of potential between these two corresponding points of the system. A line may be drawn through the zero point, and the projections on this line of the vectors representing the maximum value of any potential or e.m.f. will give their instantaneous value at any instant, it being supposed that the system rotates about the zero point once every cycle. A line drawn from the point of zero potential to the point of mean potential gives the mean potential of the system in magnitude and phase. For example, the point of mean potential of the delta-connected windings of three transformers is the centroid of the tri-

angle formed by the points representing the potentials of the terminals. If the low-tension windings are star-connected, the point of mean potential will coincide with the point representing the common connection of the three windings.

When the step-down transformers in a polyphase system are independent, the potential relations of the high and low-tension windings will be the same as those for a single-phase system. This, likewise, will be true if the secondary windings are free, but the primaries are connected. If both the primary and secondary windings are connected in groups, the rule given above for the relative

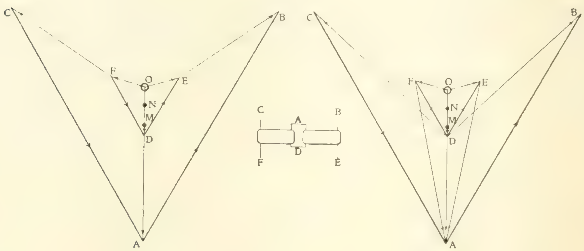


FIG. 8 FIG. 9

POTENTIAL DIAGRAMS FOR V-CONNECTED GROUPS OF TRANSFORMERS OPERATING UNDER NORMAL CONDITIONS ON A THREE-PHASE CIRCUIT. FIG. 8 APPLIES TO TRANSFORMERS OF NEGATIVE, AND FIG. 9 TO TRANSFORMERS OF POSITIVE POLARITY

The point O, at zero potential, is the centroid of the triangle ABC.

potentials of the middle points of the high and low-tension winding of a single-phase transformer must be modified, thus:—

> The potential of the point of mean potential of the low-tension system of a polyphase group of transformers is equal to the potential of the point of mean potential of the high-tension system multiplied by the ratio of the capacity between high and low-tension windings to the sum of the capacity between high and low-tension windings and the capacity between low-tension winding and ground.

THREE-PHASE SYSTEMS

The potentials of the different parts of the high and low-tension windings of the three-phase delta-delta system are shown by the vector diagram, Fig. 4, for transformers of negative polarity, and Fig. 5, for transformers of positive polarity.

The same diagram of external connections applies to both polarities, as the polarity is fixed by the internal windings and connections. It may be remarked that the secondary external connections might be rearranged so that the secondary triangle would be inverted. This, however, would produce higher stresses between the adjacent ends of the two windings. Vector diagrams similar to Figs. 4 and 5 can be drawn to scale for any particular case, and the values then obtained from the diagram by actual measurement will be sufficiently accurate for all practical purposes; but if desired the values can be calculated from the geometry of the figure.* Thus,

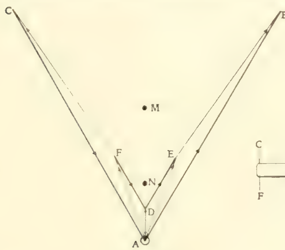
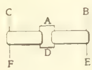


FIG. 10



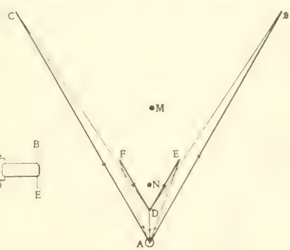


FIG. 11

POTENTIAL DIAGRAMS FOR V-CONNECTED GROUPS OF TRANSFORMERS OPERATING ON A THREE-PHASE CIRCUIT HAVING THE LINE WHICH IS ATTACHED TO *A* THE COMMON POINT OF THE HIGH-TENSION WINDING OF THE TRANSFORMERS, GROUNDED. FIG. 10 APPLIES TO TRANSFORMERS OF NEGATIVE, AND FIG. 11 TO TRANSFORMERS OF POSITIVE POLARITY.
A is at zero potential.

on the potential diagram Fig. 4, for example, *AB, BC* and *CA* represent the potentials across the high-tension windings of the three transformers; *OA* the potential of the point *A* from ground potential

**Meaning of Diagrams*—In the potential diagrams any line from the grounded point, designated by a small circle, to another point represents in magnitude and direction its potential from the ground. The letters on the potential diagrams correspond to the terminals on the diagram of connections. The relative position of lettered terminals in the small diagrams of connections indicate the external connections only. The internal arrangement may in each case be such as to give either positive or negative polarity. If in the diagram of connections for Figs. 10 and 11 the end of the primary winding to which C is connected is mechanically adjacent to the end of the secondary winding to which F is connected, the internal polarity is negative, as represented in Figure 10, in which a line joins C and F. Conversely, if the ends of the winding to which C and D are connected are mechanically adjacent, then positive internal polarity results, as shown in Figure 11, in which a line connects C to D, this line being a measure of the difference of potential between the adjacent ends of the windings.

In all cases M represents the point of mean potential of the high tension winding and N that of the low tension winding. These diagrams are based on a transformer ratio of 4:1.

(assuming the windings either ungrounded or grounded at the normal neutral point O of the system), and OB and OC the corresponding potentials above ground of B and C. Likewise, OD, OE and OF give corresponding values for the points D, E, and F of the low-tension winding.

The delta system may be grounded by means of a group of three transformers connected star-delta, by a three-phase transformer connected star-delta, or by a three-phase transformer with interconnected phases. When so grounded there can be no abnormal potential on the low-tension system since the circuit breakers will be released if a ground occurs on the line.

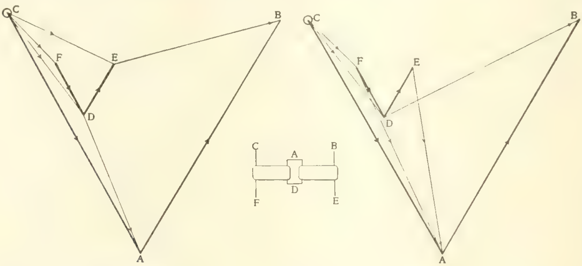


FIG. 12 FIG. 13

POTENTIAL DIAGRAMS FOR V-CONNECTED GROUPS OF TRANSFORMERS OPERATING ON A THREE-PHASE CIRCUIT WITH ONE OF THE LINES ATTACHED TO THE FREE END OF THE HIGH-TENSION WINDING GROUNDED. FIG. 12 APPLIES TO TRANSFORMERS OF NEGATIVE, AND FIG. 13 TO TRANSFORMERS OF POSITIVE POLARITY

The point C is at zero potential

The delta connection has several objectionable features when used for high voltages:—

1—Both ends of each transformer are exposed to line surges and, therefore, there is twice the possibility of trouble from this cause that there is in the case of star-connection.

2—The coils are necessarily wound with a greater number of turns of smaller cross-section, and hence are more difficult to support mechanically than those for a star-connected group.

3—Additional apparatus is usually required to obtain the neutral point for the purpose of grounding.

The potential diagrams for the star-delta system may be obtained in a similar manner to that of Figs. 4 and 5. Abnormal low-tension stresses cannot occur if the neutral point is grounded.

In this system there will be no objection to grounding the neutral, since the third harmonic does not exist in the e.m.f. between the neutral and the lines of this system. The neutral point may be used for obtaining a lower e.m.f. and a load can be taken off between neutral and one line without serious unbalancing in the delta.

V-CONNECTED SYSTEMS

The V-connection requires some consideration. Under normal operating conditions, since the center of mean potential of the transformer group does not coincide with that of the line, a constant flow of charging current through the line to ground and back through the transformer windings will occur. The diagrams, Figs. 8, 9, 10, 11, 12 and 13, serve to illustrate this system. It is assumed that the line capacity is very large compared with that of the transformer windings.

T-CONNECTION USED FOR THREE-PHASE TRANSMISSION

This connection, which is show in Fig. 14, is sometimes used in preference to a V-connection, when it is desired to use only two transformers, since the V-connection causes a somewhat greater distortion in the secondary e.m.f. than the T-connection.

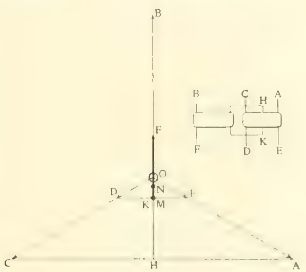


FIG. 14—POTENTIAL DIAGRAM FOR T-CONNECTED GROUP OF TRANSFORMERS OF NEGATIVE POLARITY OPERATING UNDER NORMAL CONDITIONS ON A THREE-PHASE CIRCUIT

O, the neutral point of the system, is at zero potential.

THREE-PHASE—TWO-PHASE CONNECTIONS

The potential diagram representing the conditions in the case of three-phase—two-phase transformation with normal conditions of operation are given in Fig. 15, with the usual method of connecting the two transformers. When the low-tension windings of the two transformers are connected to form a two-phase group the stresses are considerably lessened. In both the T and three-phase—two-phase connection there will be a tendency for the building up of excessive stresses in the neighborhood of the point *H* in the transformer winding *BH*. (See diagrams of connection of Figs. 14 and 15.) These stresses are due to the small impedance offered to the

TABLE II—INSULATION STRESSES IN TRANSFORMERS UNDER VARIOUS CONDITIONS OF OPERATION

System	H-T Connection	L-T. Connection	Polarity Relation	NORMAL			One H-T. Terminal at Zero			One H-T. Terminal and Neutral of L-T. at Zero			One H-T. Terminal and both H-T and L-T. Neutrals at Zero		
				Max. L-T. to Gr	Max. H-T. to Gr.	Max. H-T. to L-T.	Max. L-T. to Gr.	Max. H-T. to Gr.	Max. H-T. to L-T.	Max. L-T. to Gr.	Max. H-T. to Gr.	Max. H-T. to L-T.	Max. L-T. to Gr.	Max. H-T. to Gr.	Max. H-T. to L-T.
1 Ph.			Negative	0.50	0.50	0.45	3.00	1.00	0.70	0.50	1.00	0.95	0.50	0.50	0.45
1 Ph.			Positive	0.50	0.50	0.55	3.00	1.00	0.80	0.50	1.00	1.045	0.50	0.50	0.55
2 Ph. 4 W.	Free	Free	Negative	0.50	0.50	0.45	5.84	1.415	0.86	0.50	1.415	1.415	0.50	0.50	0.45
2 Ph. 4 W.	Free	Free	Positive	0.50	0.50	0.55	5.84	1.415	1.035	0.50	1.415	1.415	0.50	0.50	0.55
2 Ph. 3 W.	∧	Free	Negative	2.15	0.79	0.60	5.84	1.415	0.86	0.50	1.415	1.415	0.50	0.71	0.577
2 Ph. 3 W.	∧	Free	Positive	2.15	0.79	0.687	5.84	1.415	0.86	0.50	1.415	1.415	0.50	0.71	0.75
2 Ph. 3 W.	∧	∧	Negative	0.79	0.79	0.71	3.16	1.415	1.00	0.71	1.415	1.345	0.71	0.71	0.64
2 Ph. 3 W.	∧	∧	Positive	0.79	0.79	0.806	3.16	1.415	1.08	0.71	1.415	1.485	0.71	0.71	0.783
3 Phase	Y	Y	Negative	0.577	0.577	0.52	3.21	1.00	0.71	0.577	1.00	0.95	0.577	0.577	0.52
3 Phase	Y	Y	Positive	0.577	0.577	*0.577	3.21	1.00	*0.764	0.577	1.00	1.00	0.577	0.577	0.577
3 Phase	Δ	Δ	Negative	0.577	0.577	0.52	3.21	1.00	0.71	0.577	1.00	0.95	0.577	0.577	0.52
3 Phase	Δ	Δ	Positive	0.577	0.577	0.608	3.21	1.00	0.75	0.577	1.00	1.05	0.577	0.577	0.608
3 Phase	Y	Δ	Negative	0.577	0.577	0.53	3.48	1.00	0.73	0.577	1.00	0.965	0.577	0.577	0.53
3 Phase	Y	Δ	Positive	0.577	0.577	0.63	3.48	1.00	0.82	0.577	1.00	1.05	0.577	0.577	0.63
3 Phase	V	V	Negative	1.15	0.577	0.55	4.26	1.00	0.77	0.577	1.00	0.95	0.577	0.577	0.52
3 Phase	V	V	Positive	1.15	0.577	0.645	4.26	1.00	0.87	0.577	1.00	1.05	0.577	0.577	0.577

*These values are slightly increased by the triple harmonic component of the low-tension e. m. f.

passage of currents of the same frequency when flowing in opposite direction in the two parts CH and AH of the transformer winding AC. Such a condition will be a maximum when the line B is grounded. The oscillations then set up will enter the transformer AC at the points A and C and will be equal in value and of the same frequency.

SUMMARY

The potential from ground of the secondary winding of a transformer is largely determined by electrostatic induction from the primary, as well as by the e.m.f. for which the secondary is wound. These principles are illustrated in Table II which is based on transmission with transformers having a ratio of 10:1. The voltage values are given in terms of the high-tension voltage of the transformers except in the case of the V-connection, where the voltage between lines is taken as normal.

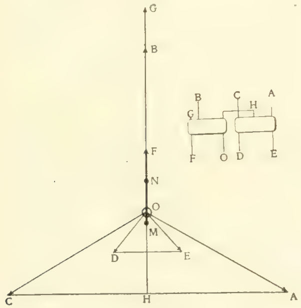


FIG. 15—POTENTIAL DIAGRAM OF A GROUP OF TRANSFORMERS OF NEGATIVE POLARITY CONNECTED FOR THREE-PHASE-TWO-PHASE TRANSFORMATION AND OPERATING UNDER NORMAL CONDITIONS ON A THREE-PHASE CIRCUIT

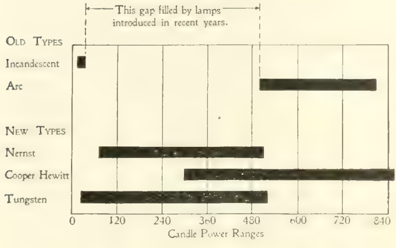
O, the neutral point of the system, is at zero potential. The three-phase lines are connected to A, B and C.

The relation $\frac{C_1}{C_1+C_2}$ applies to the transformer when the low-tension terminals are not connected to the secondary lines. When the transformer is normally connected to its load the capacity of the secondary circuit to earth is greatly increased, and, consequently, the potential of the secondary may not vary greatly from that of the earth, its value depending upon the capacity between the secondary circuit and ground. In general, the potential will be low when the circuit is long. Many of the diagrams and tables apply to the conditions in which the secondary circuit breaker is open. This indicates the occasional stresses to which the insulation may be subjected, and for which provision should be made either in the insulation or by the grounding of the circuit, or both.

NOTES ON FACTORY LIGHTING

C. E. CLEWELL

TEN YEARS ago factory electric lighting was limited to the carbon filament and arc lamp. The smaller unit, the incandescent lamp, is still very useful where the special placing of small lamps is necessary. Likewise the arc lamp is useful for large and high areas such as high bays of machine shops, foundries and the like. But neither of these serves for those intermediate conditions typified by large rooms with ceilings from twelve to eighteen feet in height. The small lamps did not give enough light unless used in large numbers, clusters often being employed which were in general expensive and unsatisfactory. The arc lamps in such cases required considerable separation and provided poor distribution with usually an intense light in the line of vision.



Within the last few years the Nernst, Cooper-Hewitt and tungsten lamps have been introduced, with candle-power values lying between those of the arc and carbon filament lamps, thus filling the gap indicated on the chart, Fig. 1, which shows the relative candle-power ranges of lamps available for factory lighting some years ago as compared with the medium sized units of the present day. These values have been taken from tables and refer to mean lower hemispherical values. The flaming arc lamp has not been included as it represents a unit of still higher candle-power.

With the introduction of these new lamps, broader possibilities have been presented in factory illumination. The use of units of sizes adapted to the purpose allows results which it has been hitherto impossible to attain satisfactorily, either by the arc or carbon filament lamp. The approximate relative efficiencies of the old and new types of lamps are indicated in Fig. 2. These efficiency values have likewise been taken from published tables and apply to the approximate efficiency in watts per candle-power. In the case of the

arc lamp the value applies to the old enclosed type of lamp.

It is evident that the introduction of these new types of lamps has made possible what may be termed a new era in factory illumination, a distinctive feature of which is the scientific installation of the light units, suiting each to the location and class of work for which it is best adapted.

THE CANDLE-POWER OF UNITS

Before the introduction in recent years of medium sized units, the choice of the size of unit for a given location was often no choice at all. In many cases, due to small clearance between cranes and ceilings, or other conditions making it necessary to mount the lamps very high above the floor, but one size or type of unit was available, the carbon filament lamp in the former and the arc lamp in the latter case.

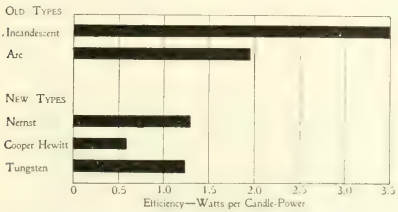


FIG 2—CHART SHOWING RELATIVE EFFICIENCIES OF OLD AND NEW TYPE LAMPS

For low ceilings up to eighteen feet the use either of the carbon filament or arc lamp resulted usually in anything but uniform light over the working plane, and often produced merely a low general light which was practically useless for the individual machines. In such cases individual lamps had to be placed over the machines. With this arrangement relatively small areas are lighted, and the metal shades usually employed only serve to accentuate the "spot-lighting" effect. Such a form of illumination for factory work is unsatisfactory and inefficient, but as stated was in many cases the only available scheme. The absence of lamps of the proper size is no longer an excuse for the existence of such conditions in industrial plants.

IMPORTANCE OF GOOD LIGHT IN FACTORY WORK

Adequate light increases output. A saving of even several minutes per day for the workmen will soon pay for the entire cost of installing and operating a suitable factory lighting system. The lighting of industrial plants is one of the factors which promotes efficiency. Like good ventilation, an adequate heating system, or cleanliness and neatness, the furnishing of good light is a necessary

item in maintaining a high standard of workmanship. In the early morning and late afternoon hours, and on cloudy days, many factories are in practical darkness as far as daylight is concerned. A good system of artificial light will be an aid in keeping production at a high efficiency throughout the entire working day. In like manner the night turn is entirely dependent on artificial light. The importance of factory lighting from this standpoint cannot be overestimated, and to be of the most service the following conditions should be fulfilled.

GENERAL REQUIREMENTS *

No factory can afford to have its employees working under

FIG. 3—FACTORY LOCATION WITH LOW CEILING WHERE 60-WATT TUNGSTEN LAMPS HAVE BEEN A SUCCESS
Glare is not noticeable.

an inadequate light, as the losses in output far overbalance any economy in the saving of energy by such means. Factory lighting should be reliable—unsteady or unreliable light is very demoralizing.

Specifically, factory lighting should provide the following features:

Adequate light for each employee.

Good light everywhere on the working plane, and, if possible, when the floor space is crowded with workmen the light should be

*Part of the following items in their specific relation to machine shops appear in substance in an article by the author in the *American Machinist* under the title, "Machine Shop Lighting."

satisfactory without regard to the location of the work; that is, the illumination should be uniform and furnished by lamps mounted overhead.

Such illumination as to make individual carbon filament lamps unnecessary except in special cases. Sometimes, however, individual lamps on machines must be provided.

Illumination provided by an arrangement and size of units which avoids glare due to light from an intense source striking the eye.

The preceding requirements should be fulfilled by a type of lamp suitable to the class of work performed, and to general physical conditions, such as clearance between cranes and ceilings.

THE OVERHEAD METHOD OF LIGHTING

A system of lighting in which the lamps are mounted above the heads of the workmen can be made to fulfill most if not all of these requirements better than other systems. The advantages of this so-called overhead system as compared with those in which individual carbon filament lamps mainly are depended upon, are as follows:

Such a system can be made to furnish good light at each point of the working plane, thus permitting work to be done with equal comfort at any point.

In many cases it can be made to furnish a light of such quality as practically to eliminate the necessity for individual lamps.

By mounting the lamps at the proper height and making a selection of the proper size, glare can be practically eliminated.

The eye is subject to a harmful effect from the use of a single lamp placed directly over and close to the work. The bright spot of light about the work, if surrounded by a region of comparative darkness, causes the eye to become fatigued since the line of vision is continually changing from the bright area to the darker surroundings. This strain on the eye can be largely avoided if the entire working surface is provided with a uniform light of moderate intensity.

Economy in maintenance is secured as compared with a system with large numbers of drop lamps.

The appearance is neater and more pleasing.

A few instances of the satisfactory results obtained with this method of lighting will serve to show with what favor it is viewed.

In one factory location with low ceilings, carbon filament clusters with individual incandescent lamps over each machine had

been in service. A system of 100-watt tungsten lamps was installed, practically all individual lamps being removed from the lathes and other machines. The whole appearance was made more cheerful. The manager stated that the problem of men desiring to be transferred to other departments on account of the darkness, was solved. Some of the workmen were overheard to say that tools and machine parts were found in corners which up to that time had been lost due to the dark surroundings, the shop receiving practically no daylight and therefore having been constantly in partial darkness.

In another instance where tungsten lamps replaced a poor

FIG. 4—A TWENTY-FIVE FOOT CEILING WHERE 250-WATT TUNGSTEN LAMPS HAVE BEEN USED TO ADVANTAGE

system of very large units supplemented by individual lamps, the superintendent stated that on many days, because of insufficient artificial light in the early morning and late afternoon hours, his workmen lost one and one-half hours per day. This condition was entirely changed by installing the overhead system. Practically all drop lamps were removed. In still another factory location a superintendent blamed defective work to inadequate light. He stated that he had had great difficulty in retaining a good class of help. Large tungsten lamps transformed the dark and dingy location to one of cheerful and pleasing appearance, and put an end to complaints.

Another factory location had been in almost complete darkness as far as overhead illumination was concerned. The almost humorous statement was made upon the installation of a good overhead system, that the men did not wear out their shoes as fast as formerly—meaning that the matter of getting around had been complicated by their stumbling against the loose iron and material which had been allowed to accumulate when the light was so poor. An inspection of the place after the new lighting system was installed showed it to be in perfect order and the floor space neat and clean. Much satisfaction was evidenced by the workmen.

The substitution of an overhead system will promote a higher efficiency of production as well as greater cheerfulness and a better spirit among the workmen, which, while difficult to express in

FIG. 5—FACTORY LOCATION WHERE 100-WATT TUNGSTEN LAMPS GIVE A UNIFORM ILLUMINATION WITH PRACTICALLY NO GLARE

money value, forms a distinct feature in the promotion of good and efficient workmanship.

SELECTION AND INSTALLATION OF UNITS

The selection of units best adapted to factory conditions and their most advantageous installation are two essential factors of shop lighting. The questions involved are: proper number and size of units; their best arrangement; economy in operation; relative first cost, and installation costs.

Number of Lamps per Unit of Floor Space—On this item depends the realization of a uniform and satisfactory distribution

of the light. Care should be taken to choose the number of units per unit floor space which will furnish a sufficiently uniform light to meet the important condition that work can be performed at any point on the floor without regard to location. The next step will be that of selecting a size and type of unit which, with correct spacing, will furnish light of sufficient intensity. An example will illustrate this point.

A large area was to be lighted and 250-watt tungsten lamps, provided in such numbers as to give a uniform and sufficient light, seemed desirable. The use of this fairly large unit would have resulted in a somewhat low first cost of installation, the number of lamps per unit area being small. There were so many workmen in each bay, however, that men located at certain positions with respect to the lamps would have worked to a disadvantage because of marked shadows. It was important that work be done with ease at any point of the floor space. In this particular instance carbon filament lamps had been used for years as drop lights over each bench. With repeated shifting of the work a continual adjustment of these drop lights was necessasry. This maintenance expense was considered sufficiently large to be a factor in the substitution of an overhead lighting system and the subsequent removal of all drop lights.

Here the use of nine 100-watt tungsten lamps per standard bay rather than four 250-watt lamps, produced a satisfactory result. It should be noted that the choice of the number of units per bay depended on the furnishing of light equally good *in direction* at any point in the bay. The use of the 250-watt lamps would have resulted in a distribution as uniform and an intensity equally great, without fulfilling the main requirement in the matter of *direction,* which in this case was the most important.

Size of Lamps—At present the size of units is a much larger factor than ever before. If the ceiling height is low, say 12 feet or under, the use of arc lamps is objectionable because of their candle-power; and besides the glare, the lamps cannot be used economically in sufficient numbers to provide uniform light distribution. Here, medium sized units have the advantage, and 60-watt and 100-watt tungsten lamps have been used successfully. Fig. 3 shows a low ceiling location where 60-watt tungsten lamps have given very satisfactory results.

For bays 40 to 60 feet in height, arc lamps, especially of the flaming type, have been used with success. For intermediate ceil-

ings from 12 to 18 feet in height, lamps of from 80 to 300 candle-power seem best adapted. Figs. 4, 5 and 6 illustrate the application of medium sized units to factory illumination.

Mounting Height of Lamps Above Floor—In factory work the mounting height of lamps will often be governed by the details of building construction and the interference of cranes. All units should be mounted so as to be out of the range of vision. This condition may be interpreted in several ways. The glare from lamps will not be so noticeable to workmen who constantly look down at their work as when the eye is for the most part on the

FIG. 6—A MODERATELY HIGH CEILING WHERE COOPER-HEWITT LAMPS HAVE GIVEN GOOD RESULTS

Note the clearness of detail.

horizontal. Again a small lamp in the line of vision will not be so harmful as a large one. One solution, when the lamps must necessarily be mounted low with respect to the floor will be to use small lamps in large numbers. This is illustrated in Fig. 3 where small tungsten lamps have been used on account of the low ceiling. Glare is probably of less importance in factory work than in offices, but is harmful nevertheless. The glare from rays of excessive brightness should be avoided because it lowers the sensitiveness of the eye. The intensity of the light on the work, while possibly ample otherwise, may seem to be insufficient due to this lack

of sensitiveness. Physically speaking the effect of glare and the subsequent eye strain is an evil, and it is evident that a workman to be of the most value should be surrounded by the most advantageous conditions for promoting ease in his work.

Another important feature connected with the mounting height is the furnishing of light at an angle so as to light the side of the tool or piece of work. The point at which the tool is making a cut may require light from an angle rather than from a point overhead. For a given spacing of lamps, the higher they are mounted the more concentrating must be the reflector to produce the highest efficiency of vertical illumination on the working surface. This vertical illumination may not, however, be the greatest feature of importance. One way to secure more light on the side of machines is to lower the lamps and use more broadly distributing reflectors than otherwise, so that the light is directed sidewise as well as vertically downward. On the other hand if the lamps are mounted too low they become objectionable by being in the line of vision when a man looks up from his work. Thus, in one instance where the maximum possible mounting height was 13 ft. 6 in., it was found desirable to place the lamps at this height to avoid glare; the side lighting was secured by using broader distributing reflectors and somewhat larger lamps than ordinarily would have been necessary, thus bringing up the vertical intensity to the same value as with the more concentrating reflectors and smaller lamps and at the same time providing the necessary side light.

Lighting Circuits—The matter of suitable lighting circuits is an important consideration. Some units are adapted to direct current only, others operate most favorably with certain frequencies of alternating current. All units to be most effective should be supplied with constant voltage. In factory work the power load will nearly always be found to exceed that for lighting. With the lighting and power circuits separate it is easier to keep the voltage on the lamps constant.

The Working Drawing—A complete self-contained working drawing of the proposed arrangement of lamps will contribute to the ease of installing a lighting system throughout a factory. Such a drawing should be intelligible to the average wiremen. It should give the outline of the floor space to be lighted and should designate the light units in some clear and distinctive form, located to scale as in Fig. 7, a typical working drawing that has been found to give satisfaction in its details. This drawing gives the dimen-

sions of the floor space, distance between lamps, and the distances between walls and lamps. The specifications should contain the number and type of lamps, the number and style of reflectors, if any, the number and type of shade holders, and the mounting height of socket above floor. The method of switch control is perhaps most easily shown on the drawing by placing the same numeral adjacent to all lamps to be controlled from a given switch. It will be found advantageous to furnish the maintenance and wiring departments with blue prints of such a drawing.

Switch Control—The switch control of the lamps in any lighting system is of importance, especially where large numbers of small or medium sized units are used. That method of controlling

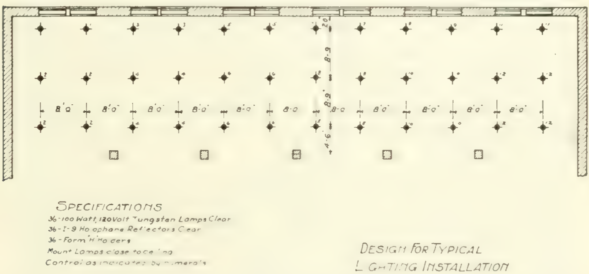


FIG. 7—A SAMPLE WORKING DRAWING WHICH HAS BEEN FOUND CONVENIENT

the lamps is most economical in which the interest, depreciation and maintenance involved in the first cost of the installation of switches and their attendant wiring does not exceed the cost of the energy saved by their use in being able to turn out the lamps which are not needed. Too great a refinement in the placing of switches may result in a first cost in excess of the saving through their use. Particularly is this the case where the factory receives little daylight, artificial light being required at all times. Here, if the number of workmen is great, practically all of the lamps will be needed all the time, and too great refinement in switch control is not warranted. In practice, however, it will usually be found advisable to install a considerable number of switches, as their cost is low in comparison with that of the energy saved by the ability to turn off the lamps in sections when not needed.

One item of considerable importance is the placing of switches

in large installations at uniform places; that is, if located on columns, the switches should be placed on columns located on the same side of the aisle and on the same relative side of each column. A fairly safe rule is to control the lamps in rows or groups parallel to the windows or skylights. This will be evident by reference to Fig. 7, where the switching is indicated by numerals adjacent to each lamp. Those lamps away from the windows will be required in many cases when the work nearer the windows is still sufficiently illuminated by daylight. If the rows of lamps are controlled in rows perpendicular to the windows, all units in a row will necessarily be on at one time, when often a portion only is needed.

FIG. 8—A FACTORY LOCATION WHERE THE LIGHTING SYSTEM WAS VERY POOR

MAINTENANCE PROBLEMS

The foremost item connected with the operation of a factory lighting system is its systematic maintenance. To furnish the best results a lighting system should be maintained with the same care which attended its installation. The factors which go to make up the maintenance include the renewals of incandescent lamps and the cleaning of reflectors and shades. In lamps possessing mechanism, repairs are necessary, and the trimming of arc lamps is the large item to be charged to a system in which they are used.

First of all, if the factory is sufficiently large to warrant it, there should be an organized maintenance department for looking after this work. This department should possess an accurate record of every lamp in the factory and its type. Arrangements should

be made for carrying in stock a sufficient supply of repair parts and renewals. It is important that a record be made of all such repairs as well as of the renewals, together with the labor involved. These records will show the maintenance cost of the various units, and will serve to indicate if this expense is excessive, due to abnormal conditions in the circuits, in the handling of lamps, or otherwise.

The designing engineer may be of service in preventing excess maintenance by seeing that the lamps are so located that the renewals may be easily made. A practical instance will indicate how the maintenance may be affected by the method of installing the lamps. In buildings of open steel construction, so called stringer

FIG. 9—A SIMILAR LOCATION IN THE SAME FACTORY AS SHOWN IN FIG. 8, SHOWING THE EFFECT AT NIGHT OF A SUPERIOR TUNGSTEN LIGHTING SYSTEM

The two photographs of Figs. 8 and 9 were given the same length of exposure and were taken at night.

boards are often placed between girders, as lamp supports. If these boards are not of sufficient strength to support a ladder, renewals and cleaning of lamps will be difficult. The higher expense for providing boards of sufficient size will be offset by the greater ease in making the renewals, thus reducing the maintenance expense.

The cleaning of glass reflectors is an important item. The depreciation of the efficiency of reflectors due to the accumulation of dust and dirt is great. The proper time to clean reflectors is when the value of the light lost, due to dust and dirt accumulations, equals the labor and material cost of cleaning them.

In order to realize the best results from such a maintenance department it is desirable that all the lighting installations be inspected once a day. An inspector making his rounds should report all lamps out of service, together with the number of lamps missing or otherwise in need of repairs. This information embodied in a report and furnished to the maintenance department in such form that all defective lamps can be located quickly, will permit of promptly replacing such lamps and will furnish at the same time a valuable record for calculating the maintenance costs.

THE RELATIVE COST FACTORS OF LIGHT

In factory lighting the manager is concerned with the cash value of the light. How much of a return in quantity and quality of work will result from the adoption of a superior system as compared with an inferior one, is the determining question. The value of good light may be placed in terms of time saved by the employee in performing a given amount of work, in the greater accuracy and perfection of the work, in the saving of the eyes of the workmen, and in promoting the facilities for better and more work by providing brighter and more cheerful surroundings. If then, better light may be interpreted in terms of so much time saved by the employee in factory operation, the equivalent in wages of this time saved is an asset of the improved lighting system.

In a case previously cited a superintendent said that his men lost from one to two hours per day on dark days due to insufficient light. This meant that the wages paid for an hour or two each day was a complete loss to the company. Often, therefore, an apparently expensive lighting equipment will prove economical. If one kind of light has a marked advantage over another, its use will result in better or more work, fewer delays, less eye strain, and in generally greater satisfaction.

The first consideration in factory lighting, if properly appreciated as an invaluable accompaniment to the quality and quantity of the work performed in a given time, is the usefulness of the light rather than the placing of too much emphasis on cost values, which are often misleading. If the factory manager can gain something of this attitude to the lighting question, viewing the matter as an asset to factory production, and will study the kind and quality of light most suitable to each condition of work, better results may be expected than when all attention is fixed on slight differences in first cost or annual charges.

WINDING OF DYNAMO-ELECTRIC MACHINES – X

ALTERNATING-CURRENT TURBO-GENERATORS

TURBO-GENERATORS present a problem in armature winding entirely different from that of any other type of machine. The steam turbine operates most efficiently at high speeds and in order to accommodate the generators to these conditions with frequencies of 25 and 60 cycles, the number of poles must be reduced to a minimum. For this reason, 60 cycle generators have been built with two poles for 3 600 r.p.m. in capacities up to 2 500 k.v.a. and with four poles for 1 800 r.p.m. up to 10 000 k.v.a. Twenty-five cycle generators are, of necessity, limited to a maximum speed of 1 500 r.p.m. They have been built with two poles in sizes up to 7 500 k.v.a.

On the other hand, the permissible diameter of a field rotating at high speeds is very small, on account of the enormous centrifugal strains produced. The internal diameter of the stator is thus severely restricted; yet the machines must be built for large outputs, and these can only be obtained by increasing the length of the armature core. A turbo-generator consequently presents the appearance of a long low machine, in comparison with the narrow machines of large diameter common to slow speed drives. The armature coils are large and unwieldy, frequently exceeding ten feet in length and 100 pounds in weight, and having a span of 30 to 40 inches. From the winders standpoint this characteristic largeness and clumsiness of the coils, combined with the small diameter of the stator bore, form the chief difference between the turbo-generator windings and any other type.

The pitch of a turbo-generator is always large; on a two-pole machine, for example, it is half the circumference of the core. A full pitch winding thus involves a large amount of copper in the end connections and requires considerable space at the ends of the armature. With a fractional pitch, both the amount of copper and the space required for the end connections can be much decreased and a wave form can be produced which is very close to a perfect sine. The flux enclosed by a coil with a fractional pitch is, of course, less than with a full pitch winding. With a small departure from the full pitch the loss of potential is slight, however, as shown by Table I, and the advantages to be gained are so great

that it is common practice to use fractional pitch windings for turbo-generators.

THE CORE

Although the methods of core assembly for a turbo-generator are the same as for any alternating-current stator, the dimensions and general appearance are quite different. The most noticeable distinction lies in the large size of the slots and in the depth of the core, due to the small number of poles. Vent plates are inserted in order to provide thorough ventilation, the frame being designed for complete enclosure so that the cooling air may be drawn from outside the power station. Cooler and frequently cleaner air than can be secured from inside the station may thus be used for ventilation. The core is retained in place by heavy end plates, which are keyed to the frame. In addition, on the larger sized machines, insulated bolts pass entirely through the core as an additional support to prevent flaring of the iron.

TABLE I—RATIO OF PITCH TO GENERATED POTENTIAL

Percent Pitch	100	90	80	70	60	50	40
Percent Potential	100	99	95	89	81	71	59

THE COILS

Turbo-generators have open slots, and the coils may be either diamond or involute, usually diamond. Either type of coil may be built in two-piece form, with one or several turns per slot. The two-piece coil is used where the throw of the coils is very great, as in large size bipolar machines for 25 cycles. The one-piece coil is used almost exclusively on the smaller machines, and in fact, wherever such a coil is not too cumbersome to handle, provided the complete coil can be passed through the bore. The coils of either type may be formed from cotton covered strap or cotton covered wire. Where a conductor of large cross-section is desired, it is ordinarily built up of a number of square copper wires in parallel, to facilitate bending and to obtain proper lamination. The individual strands are usually cotton covered. Most turbo-generators require more than one turn per slot in order to obtain the desired voltage. These several turns are bound together in a me-

chanical unit, insulated from each other and insulated as a group from the frame of the machine.

The coils may have their end connections bent down at any angle whatsoever, from zero to 90 degrees. The involute coils, of course, lie flat against the face of the frame as shown in Fig. 118. In practice, the diamond coils are always bent down at the ends from 30 to 60 degrees, both to provide ample clearance and ready access to the rotor, and in order that they may be more suitably braced, as shown in Fig. 119. Especial care is taken to so shape the coil ends as shown in Fig. 120 that cool air can circulate freely through them. Coils of several turns sometimes have the individual turns insulated separately after they leave the slots to give greater cooling surface to the ends.

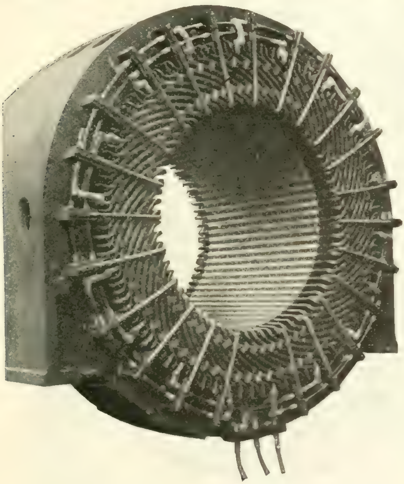


FIG. 118—TURBO-GENERATOR WOUND WITH INVOLUTE OR 90 DEGREE COILS

FORMING THE COILS

Except for conductors of large capacity, the conductors are formed from a single copper strap. The process of forming the coil is the same whether each conductor consists of one bar or several bars or straps in parallel, each group of wires or straps which make up a conductor in the latter case being formed as a single strap and then bound together with tape and treated as a unit. For a one-conductor coil, designated as an open coil, a strap of suitable length is bent at the middle around a pin, forming a U with the sides separated very slightly. This loop is then mounted directly in a mould. A steel pin through the bend of the U serves to hold the point of the diamond vertical while the sides are bent to conform to the shape of the mould. Coils of several conductors are sometimes built in this same way, by forming

the individual conductors in a group with a copper strip of the same thickness as the insulation inserted between them. The conductors are separated and insulated from one another, and are then insulated from ground the same as a one-conductor coil, the several conductors being connected in series when placed in the machine.

A coil of more than one conductor formed from a single strap is known as a closed coil and requires several operations. The strap is first wound around pins set in a flat table, to the required

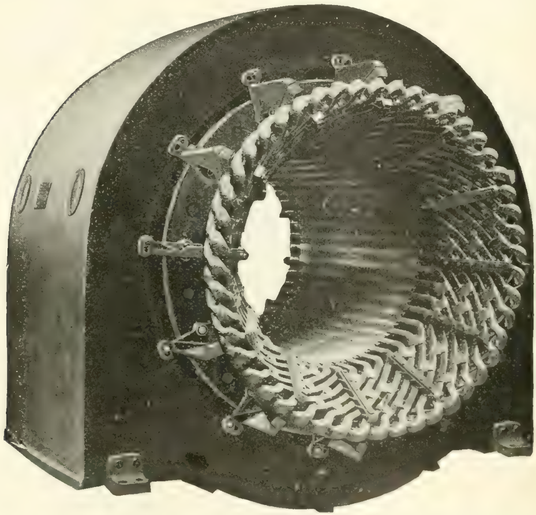


FIG. 119—2 500 K.V.A TURBO-GENERATOR, WOUND WITH DIAMOND COILS

number of turns, and is then given its final shape by forming over a mould. Throughout the entire operation the conductors are kept apart by straps of metal to the same distance that they will be separated when insulated and placed in the machine.

Two-piece coils are formed from lengths of straight copper strap. The ends are bent at a suitable angle to the straight part of the coil around two pins spaced a distance equal to the length of the straight part. The conductor is then clamped in a mould and the ends are bent into shape. The several conductors in a coil are

formed in the same mould, they being separated as before by strips of copper strap.*

INSULATION

Since a turbo-generator may at times be subjected to very heavy overloads, the insulation should be as nearly heat proof as possible. For this reason, mica is used to as large an extent as practicable. Where several conductors per coil are used, the insulation between conductors usually consists of flexible mica tape

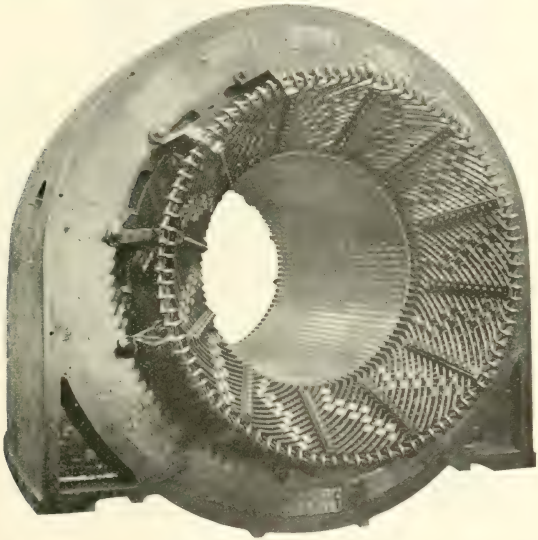


FIG. 120—5 000 K.V.A. TURBO-GENERATOR, WOUND WITH DIAMOND COILS

and mica cells. The individual conductors are then suitably bound together.

All coils are impregnated with an insulating compound before the insulation from ground is supplied. The straight parts may be clamped tightly in metal clamps and impregnated, or may be impregnated without the clamps and placed in clamps to dry. Either method results in a compact, uniform construction so that the coil

*Fig. 3 of the article by Mr. Clewell on Factory Lighting, page 280 of the present issue, shows a number of turbo-generator coils of different types in various stages of winding.

may be fitted tightly into the slot with minimum risk of damaging the insulation.

The insulation from ground consists of wrappers of paper and mica over the straight part. The coil ends are insulated by layers of treated tape, with a covering of untreated tape, and the whole is treated with insulating varnish. As in the case of engine type generators, if extra insulation is required additional wrappers

FIG. 121—TURBO-GENERATOR PARTLY WOUND
Operator binding coils in position

of the paper and mica are frequently used, the coil being dipped and dried after each wrapper is applied. This makes the building of a high voltage coil a long process, two weeks or more frequently being required for the completion of a single coil.

Testing—Open coils are tested for short-circuits by applying a suitable voltage between conductors. No short-circuit tests are made on the individual closed coils, but an over-voltage test is applied after they are on the machine. All coils are tested for insulation by wrapping the outside with tin foil, and applying from

two to two and one-half times normal operating voltage across the insulation.

WINDING THE ARMATURE

Except for the great weight and large size of the coils which makes them more difficult to handle, the winding of a turbo-generator is in all essentials similar to the winding of an engine type generator. The straight part of the coil is waxed and laid over the slot opening, inside a paper cell with which the latter is lined. In order to avoid bending the coil, a wooden drift as long as the straight part is used to drive it into the bottom of the slot. The bottom halves of two-part coils are inserted first in all slots in the span of one coil, the top halves being inserted later. One-piece coils are inserted in regular order.

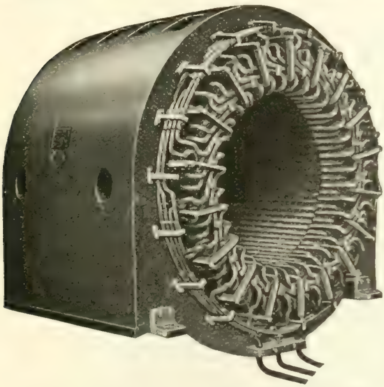


FIG. 122—3 000 K.V.A. TURBO-GENERATOR WITH ONE-COIL-PER-SLOT WINDING

As each top coil is fitted into place, the cell which lines the slot is folded over, and retaining wedges, in short sections, are driven in place over the full length of the coil, enough strips of extra material being used in the slot to make the wedges fit tightly over the coil. The wedges are driven in place by a tool of special shape, operated by a compressed air hammer.

In order to get the bottom half of the last few one-piece coils into the slot it is necessary to lift the top half of the coils which go in the same slots. With a full pitch winding this would mean one-half of the coils on a two-pole machine, and one fourth the coils on a four-pole machine. With a "chorded" or fractional pitch winding, however, the number of throw coils is less. The throw of the coils can be readily seen in Fig. 121, which shows a generator partly wound with one-piece coils.

In some cases, the improved space factor that can be secured makes it worth while to use a one-coil-per-slot winding. This

winding is inserted in the same way as the two-coil-per-slot windings, except that alternate slots contain, respectively, front and rear ends of coils as shown in Fig. 122.

BRACING

The instantaneous current which flows in case of short-circuit on a turbo-generator or, in fact, any other generator, is very large and the magnetic stresses, which vary as the square of the current and the span of the end windings are consequently enormous in the

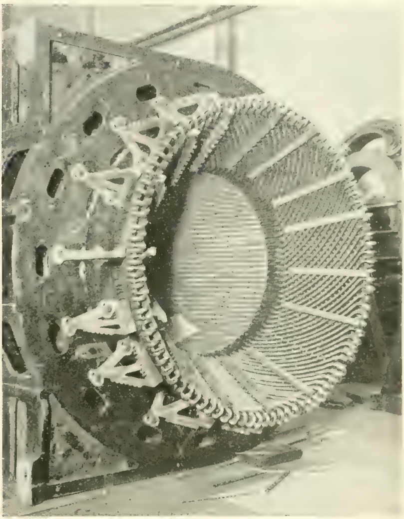


FIG. 123—10 000 K.V.A., 11 000 VOLT TURBO-GENERATOR PARTLY WOUND
Bracing and connecting of coils not completed

turbo-generator. For this reason adequate bracing of the coil ends is of supreme importance. Greatest reliance is placed on metallic braces securely bolted to the generator frame. For the involute coils the braces consist of U shaped clevises which are thoroughly insulated with treated tape and bolted to the machine frame at the ends through spacers, as shown in Fig. 118. For diamond coils, the braces take the form of malleable iron brackets bolted to the frame. The coils are rigidly secured to these braces by non-

metallic clamps, reinforced by brass plates, as shown in Fig. 120 and 123 and fastened to the braces by insulated bolts.

CONNECTING

Turbine windings are almost always connected with one group of coils per pole per phase. The coils of each group are connected in series, as shown in Fig. 123. In some cases these connectors are riveted as well as soldered in place. The groups per phase may be connected in parallel or series, depending on the requirements of the machine; ordinarily the latter on machines of 2 200 volts or higher. The end connections are fully insulated and are

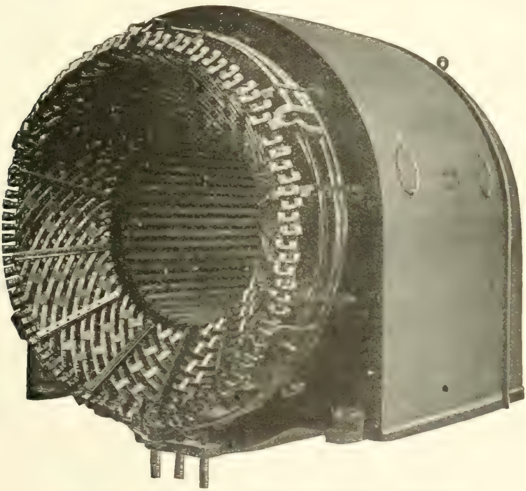


FIG. 124—2 140 K.V.A. TURBO-GENERATOR, SHOWING END CONNECTIONS

support on the rear of the braces, as shown in Figs. 118, 122 and 124.

TESTING

After all the coils have been placed in the core, their free ends are connected together and the standard break-down voltage is applied from the copper to the machine. A similar break-down test is applied between phases after the coils have been connected into groups. No further tests are applied until the final load tests are run on the assembled machine.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal Box 911, Pittsburgh, Pa.

529—Special Two-Phase — Three Phase Transformer Connection— When repairing a two-phase induction motor some time ago, I found the transformers to be connected as shown in Fig. 529 (a). Will you kindly explain this connection? The transformers were 2 200 volt, primary, and were connected to two wires of a 4 000 volt, three-phase circuit with grounded neutral. A. G.

On the primary side the impressed voltages are of course 120

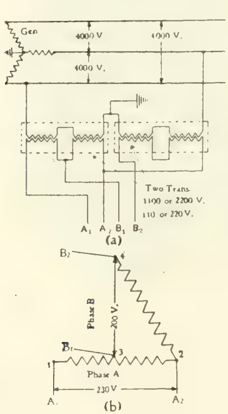


Fig. 529 (a) and (b)

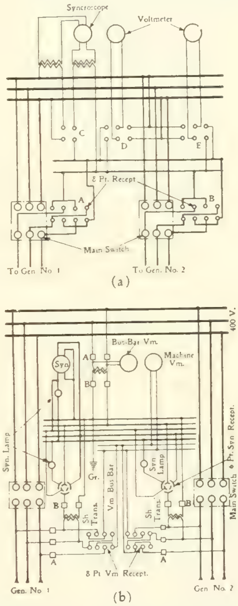
degrees apart, but on the secondary side one phase is reversed, giving the 60-degree relation shown in Fig. 529 (b). Assuming a ratio of transformation of 10 to 1, the two-phase voltages are, then, 1 - 2 and 3 - 4, which are respectively 230 volts and 200 volts at no load, when 4 000 volts three-phase is applied on the primary line. Phase *A* draws current through transformer *A*, and phase *B* draws current through transformer *B* and half of transformer *A*. One-half of the latter transformer, therefore, carries the current of both phases. Since these two currents are 90 degrees apart, the resultant in this part of the winding when both phases are carrying full load will be 41 percent greater than normal full-load current. In other words, this winding will be fully loaded when each phase is carrying but 71 percent (1÷1.41) of full load. Since the capacity of the bank is limited by the capacity of that winding in which there is the greatest heating, it will be seen that this connection has but 71 percent of the combined rated capacity of the individual transformers.

E. C. S.

530—Synchronizing Connections— In a power station in which four 400 volt alternators operate in parallel much trouble has been experienced from short-circuits across the eight-point synchronizing plug receptacles. The secondary potential of the synchronizing transformer is 100 volts. The present connections are shown in Fig. 530 (a). Occasionally a plug will be inserted by mistake in two of the receptacles at the same time, which of course causes a short-circuit. The blowing of the plug fuse does not stop the trouble, but there is invariably a flash across the receptacle terminals which destroys them and the plug. In one or two instances similar short-circuits have apparently been started by surges in the transmission line. To remedy this trouble three schemes have been suggested. In two of these, it is proposed to use three syn-

chronizing plug receptacles, four points each. One of these will serve to make the proper connections to the synchroscope in synchronizing either machine. Each of the other receptacles will respectively serve to make the proper connections for an individual machine. In the first proposed arrangement,each of the latter two receptacles will serve to open one side of the primary circuit of the corresponding synchronizing transformer and one side of its secondary as well, in this way eliminating the constant loss due to the synchronizing transformer being always connected to the line. In the second proposed arrangement the only difference would be that the secondary circuits of the two transformers would be disconnected when the plugs were not in receptacles, their primary circuits being permanently connected. The third proposed arrangement would simply provide for the insertion of low capacity fuses in the leads connecting the plug receptacles to the respective generator circuits. Elimination of the possibility of these short-circuits and the resulting danger involved in the process of synchronizing will greatly simplify this important operation. Please give the relative merits of the three proposed methods. C. L. G.

The scheme of synchronizing involving the least number of operations is essentially the best, and Fig. 530 (b) shows a scheme of connections which is preferable to those proposed. The voltmeter connections are separated from the synchronizing connections, and one voltmeter is used to read the voltage of any phase of either machine by means of the eight-point voltmeter receptacle, while the second voltmeter is connected permanently to the bus-bars. This arrangement permits a comparison of the voltages of the incoming and running machines during synchronizing. But one synchronizing plug is used with the various synchronizing receptacles, this plug being inserted in the receptacle of the generator panel controlling the incoming machine. When there are to be but two generators, synchronizing may be done between machines instead of from machine to bus-bar, as shown in the diagram, it being possible in this case to omit one shunt transformer and



Figs. 530 (a) and (b)—Present and revised connections for synchronizing between any two generators of station

A=600 volt, one-ampere fuse
B=250 volt, one-ampere fuse

one synchronizing receptacle. The synchronizing lamps and wiring for them may be omitted if they are not desired, in which case a four point receptacle may be used for the synchronizing receptacles. The method of connection shown in Fig. 530 (b) is to be recommended, however, as the synchroscope, synchronizing lamps and voltmeters all aid the operator in the synchronizing operation. The fuses shown in the potential cir-

cuits may be enclosed fuses mounted in Edison plug cut-outs on the rear of the board. With the fuses mounted in this manner there should be no danger to attendants, and with the connections as shown and the use of *only one synchronizing plug* and *one voltmeter plug* there is little risk of blowing a fuse. Fig. 530 (a) has the objection that, when synchronizing generator No. 1 with the bus-bars, one plug must be inserted in the middle position of receptacle *A* and another in receptacle *C* to obtain a voltage comparison and two more plugs must be inserted in the left hand position of receptacles *D* and *E*, thus permitting of a number of chances for mistakes. The first proposed modification is an improvement over Fig. 530 (a), but two plugs are still required to synchronize, and simplicity is effected by omitting the voltmeter connections. The second proposed modification is not as good as the first for this particular voltage, as in the first the receptacle disconnects the primary as well as the secondary, thereby eliminating the transformer losses when it is not in use. For higher voltages, however, the second modification would be preferable to the first, as the opening of the primary of the transformer would then require a high-voltage switch. C. H. S.

531 — Starting Interpole Motor-Generator Set—A large interpole generator driven by a synchronous motor is started from the direct-current side but takes more current than is usual with machines of this size. What effect would short-circuiting the interpole circuit have; would the machine start more readily, or would this be a dangerous proceeding? G. A. R.

Short-circuiting the interpole coils would result in serious sparking without effecting a reduction in the starting current. If the generator is compound-wound the best way to reduce the starting current is to reverse the series coils so that the machine will operate as a compound motor, at the same time increasing the shunt field current; a double-pole, double-throw switch is usually connected in the direct-current series circuit for this purpose. If the generator is a shunt-wound machine the shunt field current should be as large as possible during starting. W. A. D.

532—Energy Consumption of Alternating-Current Arc Lamps—This village has 30 multiple arc lamps, operated from a 250 volt, three-phase generator. The lamps take six amperes. The generator was owned by a mining company, which has now removed it, and the village is going to install a 2300 volt, 50 kw generator. Now the village wishes to operate these lamps without any change. Therefore, we will locate a transformer centrally in the village and supply power to the arc circuit at 250 volts. Of course it may be better practice to discard the old lamps and put in series type, but the above is what they want. It surprised me to note, when I examined the lamps, that they were rated at six amperes, and I would like some information on this point. I do not suppose these lamps consume more energy than a lamp taking 2.5 amperes at 250 volts on direct-current. But the apparent consumption is $6 \times 250 = 1500$ watts. Is this apparent consumption equivalent to 1.5 k.v.a.? If the real consumption is in the neighborhood of 600 watts, what is the power-factor of these lamps? Much less than 80 percent and I thought all arc lamps had about that figure. What will be the capacity of a transformer to operate this circuit of 30 lamps? Assuming they require 600 watts per lamp, will an 18 kw unit do or must we have one of 45 kw capacity? J. F. S.

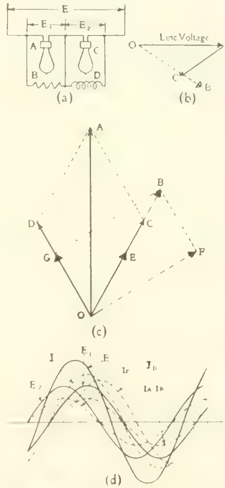
If the lamps are equipped with a choke coil inside the case and are rated at six amperes—then they take six amperes at the terminals, and on a 250 volt circuit will take 1.5 k.v.a. at the terminals. The required transformer capacity for 30 such lamps will be 45 k.v.a. If the lamps are of modern make an auto-transformer will be used inside the case. Such a lamp taking

six amperes at the arc will take about 2.8 amperes at the terminals and on a 250 volt circuit it will take about 0.7 k.v.a. The transformer capacity for 30 such lamps would be 21 k.v.a. If lamps of the choke coil design are in use on 250 volts it is obviously very poor economy to continue their use; for, by installing modern lamps twice as many could be operated for the same k.v.a. generator capacity, at the same time giving better results. For further information regarding the effect of low power-factor load on generator capacity requirements note JOURNAL Question Box references under "Power-Factor," p. 18, in The Six Year Topical Index; article on "Alternating-Current Generators," by Mr. P. M. Lincoln, in the JOURNAL for Nov. and Dec., 1906, and article on "Rational Selection of Generators," by Mr. F. D. Newbury, Oct., 1909, p. 584.

D. A. B.

533—Incandescent Lamp Voltage Raised by Paralleling with Inductive and Non-Inductive Resistances—Two lamps in series have a constant alternating potential maintained across them. If one lamp is shunted by a suitable inductive resistance and the other by a non-inductive resistance; as indicated in Fig. 533 (a) they glow more brightly; i. e., more current passes through them. How is it that the ordinary method of making alternating-current calculations does not indicate this? What modification must be made in the ordinary method in order to indicate it? J. P.

The ordinary method of making alternating-current calculations covers the case stated. If the lamps are considered as voltmeters, indicating rise of voltage by increased brilliancy, the case is reduced to the familiar one of demonstrating that the sum of the voltages across an inductive and non-inductive resistance in series is not equal to their algebraic sum but to their vector sum. When only the two lamps are in circuit it is practically non-inductive, the voltages across the lamps are in phase, and are each equal to one-half of the line voltage. When the shunts are closed across the lamps the circuit becomes inductive and the current lags behind the line voltage. Fig. 533 (b) shows this condition. Let OA be the line voltage, OB the current and the angle AOB the phase angle of the resultant current in the line. The lamp with non-in-



Figs. 533 (a), (b), (c) and (d)

ductive shunt will have a voltage across it which will be in phase with the current and which can be represented by OC. Since the voltage across the second lamp and inductive shunt is the vector difference between OA and OC it is represented by CA. When the relation of the inductance and resistance is such as to leave the two lamps burning with equal brilliancy, then OC equals CA and each is greater than one-half of OA. The diagrams, Figs. 533 (c) and (d), show the phase relation and relative magnitude of the currents and voltages in the circuit of Fig. 533 (a), assuming the inductive shunt to be of such value that the current in the line lags 30 degrees, that the non-inductive shunt equals one lamp in resistance, and that the lamps burn with equal brilliancy.

Fig. 533 (c) is the vector diagram for the circuit and the vectors are as follows: OA = line voltage E; OB = line current I; OC = voltage E_1; OD = voltage E_2; OE = current in lamp A and non-inductive shunt B; OG = current in lamp C; and OF = current in inductive shunt D. Fig. 533 (d) shows the curves of instantaneous values of all currents and voltages and is obtained by revolving Fig. 533 (c) counter-clockwise about O and taking the successive values of the vertical projections of the several vectors. L.W.C.

534—Unbalanced Load on Three-Phase System—What would be the effect on the regulation of the generator or possible disturbance if the load at point "*B*," Fig. 534 (a) were carried by the generating station at *A* as an optional source of power? Power is ordinarily delivered to points *A* and *B* by a transmission company; however, in case of emergency, power is developed at *A* to supply current at *A* only, the latter requiring 60 kw, three-phase load, practically non-inductive. J. R. K.

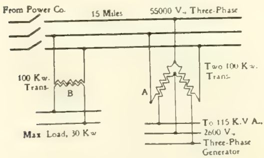
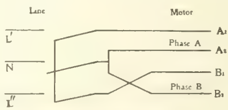


Fig. 534 (a)

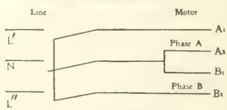
It is assumed that under certain conditions the loads at *A* and *B* are to be supplied from the 115 k.v.a. generator, the load at *B* being fed through the transformers and line as shown. The 30 kw at *B* then comes through the two transformers in "V", these acting in this case simply as two transformers connected in series single-phase and operating at half voltage. Hence, for normal heating they can deliver but one-half their rating, or 100 kw to the single-phase load at *B*. Since this load is but 30 kw no trouble will be experienced. The *B* load is paralleled at *A* with a three-phase load of 60 kw, thus making a total of 20 kw per phase on two phases, and 20 + 30, or 50 kw on the third phase, i. e., 90 kw in all. The effect is to produce unbalanced regulation on the different phases of the generator and to cause two of the windings, if star-connected, to carry more than their rated current. The overload in these windings may be as great as 25 percent when the power-factors of loads *A* and *B* are approximately the same on the external loads at these points. E. C. S.

Note

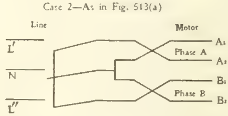
Referring to No. 513, Dec., 1910, relating to methods of reversing a two-phase motor on a two-phase three-wire line, it has been suggested that diagrams be given showing the original connections and the three reversing connections noted therein.



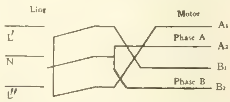
Case 1—Original Connections



Case 2—As in Fig. 513(a)



Case 3



Case 4

In the accompanying diagrams *case 1* represents original connections; *case 2*, reversal of motor by reversing connections of phase *B* (see Fig. 513 a); *case 3*, reversal by reversing phase *A*; *case 4*, reversing two of the three line connections to the motor, the neutral connections remaining unchanged.

THE

ELECTRIC JOURNAL

Vol. VIII APRIL, 1911 No. 4

Government and the Corporations

Notable views regarding corporations were expressed in the addresses of Mr. George W. Perkins and Mr. George Westinghouse before the Southern Commercial Congress, held in Atlanta last month. Mr. Westinghouse, whose address is reproduced in this issue of the JOURNAL, proposes that power companies should not merely be allowed to consolidate, but should be compelled to do so, in order that the many advantages of operation on a large scale may be secured.

Mr. Perkins, speaking on "Modern Industrialism," shows how the physical or engineering side of modern affairs has advanced much more rapidly than the moral or human side. The lawmaker and the business man are not keeping pace with the inventor and the engineer. The fundamental conditions which underlie many of the social, industrial, commercial and legal problems of the present time are well presented by Mr. Perkins in the following paragraphs:—

"The last one hundred years has been the supreme day of the inventor. Steam and electricity in his hands have annihilated distance and brought the people of the world face to face with one another and, therefore, face to face with entirely new problems in commercial affairs.

"While this startling transformation has been taking place, lawmakers in the United States have not been idle; they have been as active as have been the inventors. Myriads of laws have been passed, having as their sole object the restricting, limiting and curtailing of business. While the inventor has been expanding the business man's opportunities, the lawmaker has been endeavoring to contract them. The clashing of these two great forces is largely responsible for our present conditions. While laws have been enacted having as their purpose the prevention of business getting together, we have had the uses of steam and electricity so perfected that the business world has been irresistibly drawn together, and the attempts of man to make laws that will nullify conditions

that have come about through the conquest of the mysteries of Nature will never permanently succeed. One might just as well attempt to legislate against lightning.

"A corporation is a composite of steam, electricity and men. We have learned how to regulate and control steam and electricity. Let us teach ourselves how to regulate and control a corporation.

"While the agitation of recent years has been unfair and harmful in many instances, it has set business men thinking, has awakened the business conscience, and has brought a new realization of the fact that it is as true of business as it is of the individual that there is no permanent success unless it be based upon integrity of character."

The Electrical Possibilities of the South

Anything said about the present or future of the work of the Southern Power Company, so ably outlined by Mr. Magraw in this issue of the JOURNAL, would naturally refer to cotton, for there is no other great industry so absolutely dominated by any one country as to be even mentioned in comparison with cotton. That portion of the present crop, which has been shipped from the South to be manufactured elsewhere, will bring over six hundred million dollars, a greater sum than the world's gold and silver production. When converted into the various yarns, fabrics, laces, etc., manufactured in the North and abroad, it could safely be appraised at three times this amount. If the mills in the South would increase at the same rate as the demand for manufactured goods, this vast amount would remain here to enrich the country to which it normally belongs. That the South can produce several times the amount of raw cotton it is now growing is well known to all familiar with the prevailing conditions; and that the demand will soon be made upon it to do this is equally well known by those who are familiar with the new channels open for the use of cotton.

Of the one hundred and twenty-four million cotton spindles in operation in the world, twenty-eight million are located in the United States, and twelve million of these in the South. Sixty percent of the latter are located in the territory shown on the map of the Southern Power Company's transmission lines in Mr. Magraw's article. These mills represent an investment of one hundred and seventy-five million dollars and produce annually man-

ufactured goods worth approximately three hundred million. They manufacture only thirteen percent of the cotton grown in the South, and only recently have they gone into the spinning of fine yarns. Thirty years ago there was in operation in this same district less than three percent of the present number of spindles.

That the growth of the manufacture of cotton goods in the South has been normal and that the future growth is assured is evidenced by the natural advantages which this country possesses; the proximity to raw material, the unsurpassed climate of the Piedmont region, good transportation facilities, a plentiful supply of labor and an abundance of cheap power.

With these facts before them, it is not surprising that men who have watched the South come out of poverty into wealth, should devote their energies and money to the upbuilding of two very important links in the chain of natural advantages. That they in no way overestimated the opportunity is seen by a glance at the load curve given by Mr. Magraw. In the seven years of operation, it shows a growth of business that is exceptional and, at first glance, seems phenomenal. When work was started on the first hydro-electric development, the electric drive of cotton mills was new and almost unheard of. The mills were using a drive that seemed quite satisfactory to them and investors were loath to increase their capitalization for something untried. The larger mills were producing power from steam at a cost that would hardly warrant the change, were there no other advantages. The explanation is that the mills saw in the change a greatly increased production. The substitution of the turbine and electric drive for the reciprocating engine gave the spindle uniform speed, and the centralization of power left the mill's superintendent more time to devote to the perfection of his product. Also the output of the various parts of the mill could be adjusted for production balance by speeding up or running any department overtime. In confirmation of this, it is noteworthy that the curve rises slowly at first, but turns up as soon as sufficient time had been given the electrically driven mills to demonstrate their superiority.

Not more than seventy-five percent of the mills in North and South Carolina can be considered as a possible load, as the other twenty-five percent are operated from water powers owned by the mills. Nearly half of the former are now driven by the Southern Power Company, and a large part of the other half will be reached by the lines under construction. More specifically, this company supplies power to one hundred and fifty-two cotton mills, several

oil mills, forty cotton gins, six street car systems, and the lighting and power load in forty-five towns and villages.

It is estimated that the present load carried by the system is equivalent to the energy of over a million tons of coal annually. By the building of dams, power houses and transmission lines, this energy has been conserved from a source that up to that time had been going absolutely to waste.

The economic question that arises is: Has new business really been created, or have channels of commerce simply been diverted?

If an increase of production in cotton mills was all that had been accomplished by this large expenditure of capital, the investment would be justified, but the benefits, we believe, have wider ramifications. The mills, the towns and the cities, and the country, have profited in other ways. Labor and material used in construction require the expenditure of a large amount of money locally; and the supervision of work of this nature brings in many men who are valuable as a city asset. Furthermore, when a company and its consumers buy largely, their center of operation receives considerable attention from manufacturers. Local offices and distributing points are opened, which bring in more valuable city material. The railway, the hotel, the merchant, the land owner, the manufacturer and the professional man, are directly benefited; but perhaps more valuable than any of these is the advertisment received from the engineers, salesmen and business men who, from time to time, visit the scene of operation. The direct result is the establishment of new industries and a general increase in activity which help to make permanent advancement to the whole district.

Great as may be the influence of these factor in the upbuilding of local business, even greater, we believe, is the impetus given the South in general by the confidence shown by men of broad experience in investing their money in an enterprise that must stand or fall by the success or failure of the business men living in this country and conducting its business. These investors are going hand in hand with the men of the South, and the South's success is their success; the South's failure their failure. Fortunately, the success of the work is not in doubt, and, in the light of the things that have already been accomplished by the men who have covered this section of the country with a network of transmission lines and have under construction hundreds of miles of electric railway, we are assured that the ultimate benefits to the South will be many, many times greater than the present individual benefits to the mills.

J. W. Fraser

Iron Loss Measurements

We always admire the mathematician who can go through a very complicated mathematical demonstration and arrive at a correct result; we sometimes fail to appreciate the still greater achievement of him who, understanding the mathematics of the case, can arrive at a simple solution of the same problem in such a way that even the uninitiated can understand the steps, or can perform them mechanically without the necessity of understanding them.

The iron loss voltmeter and the results obtained by its use, described in the article entitled "Testing Transformer Iron Losses on Sine Wave Basis," in this issue is a case similar to that cited above. Here a method is found which simply and automatically takes care of a number of disturbing influences which enter into and complicate the testing of the iron loss of transformers. This method has been in use in the testing department of the Westinghouse Electric & Manufacturing Company for about three years; it is there known as "the fool-proof method," and Mr. Spooner's results check with those obtained in a long series of tests made before its adoption. The simplicity and accuracy of the method is of the greatest value in routine factory testing, as it eliminates the necessity for a special generator for iron loss measurements; entirely satisfactory tests can be made on a system where the generators supplying the system are either lightly or fully loaded, and where the voltage wave is subject to frequent variations.

The iron loss voltmeter is also useful in connection with temperature tests on transformers; it allows such tests to be made on the basis of *normal iron loss* and rated current, in place of *normal voltage* and rated current, as is the usual practice. Since using this method of making temperature measurements, many readings which were considered inaccurate due to thermometer calibration, bad placing of thermometers, variation of current, etc., have been completely eliminated, for with the use of the iron loss voltmeter the actual iron loss in the transformer can be kept constant.

Anyone familiar with the reading of electrical instruments can make entirely satisfactory iron loss tests with this meter and be sure that the results are as accurate as the best that can be obtained by one skilled in taking wave shapes and making all the corrections incident to the methods formerly available for this work.

C. E. Skinner

The New View of Industrial Training

Should the public school and the technical school equip their graduates for taking up their vocational work immediately, or should apprentice or training courses be provided in the various industries. During the past decade the graduate of the technical school has come into general favor, possibly because he is no longer expected to be a trained practical expert when he receives his diploma, but is presumed to have a preliminary training so that he can quickly acquire the special training and the practical experience in his chosen vocation.

Likewise, there is a growing belief that neither the public schools nor manual training schools should be expected to supply trained men, but that the industries themselves should furnish training by apprenticeship courses. This is because it is not the function of the schools to teach trades. It is their function to furnish good beginners and the trade itself should be learned while working in the trade. Manufacturers have usually looked upon an apprenticeship course with class-room adjuncts, with little favor. If the new view is the correct one, if it is essential that the training upon which the life and growth of industry is to depend must be fostered within the industry itself, and if the problem of transforming the unskilled into the skilled is one which, in a large measure, the industries themselves must solve, then the problem becomes of fundamental consequence in our industrial progress.

Modern conditions have created a new need for trained men, for engineers on the one hand and for skilled workmen on the other, which has already brought about great changes in engineering schools, which should bring about changes in our public schools and which is bringing about new methods in the training of men in the industries themselves.

The new apprenticeship with its new aims and new methods and its far-reaching possibilities, was presented at a recent meeting in Boston of the National Society for the Promotion of Industrial Education. The whole subject is of such vital interest to those interested in education and in industry that the substance of the several papers presented is given in this issue of the JOURNAL.

CHAS. F. SCOTT

ELECTRICITY IN THE DEVELOPMENT OF THE SOUTH*

GEORGE WESTINGHOUSE

IF we examine broadly the changes which have come about in industrial methods and in the means of transportation since the invention of the steam engine, it will be found that the application of power has been the fundamental factor in bringing about the characteristic conditions of the era in which we live. The steam vessel and the steam locomotive, by revolutionizing transportation methods, made possible the present development of our country. It is the power of the steam engine or the waterwheel which has substituted the power loom for the hand loom, with all the marvelous results which have followed. Similarly, throughout nearly every industry, human muscle is no longer the source of power, for the hand now directs and controls the untiring and unlimited power of great engines. Reduced to its ultimate terms, the vital forces in industry and in transportation come from coal mines and waterfalls, resources with which the South is abundantly blessed, and the problem is to secure power from these sources and to utilize it in building up the industrial and commercial life of the community.

THE AGE OF ELECTRICITY

Had a Jules Verne sought to imagine some universal servant of mankind, he would well have depicted some magic agent which would apply Nature's forces to do man's work; which could take the energy of her hidden coal, of the air, or of her falling water, carry it by easy channels and cause it to give the light of a million candles, the power of a thousand men, or to move great loads faster than horses could travel, to produce heat without combustion, and to unlock chemical bonds and release new materials. No such wonder was pictured by the imagination of the seers of the past; and yet a subtle force which transcends the powers of the imagination is daily doing all these things—a vitalizing force, which is already stimulating the physical recovery of the South; and if we still think of the present as the era of steam and steel, unquestionably the coming epoch, whose dawn we are privileged to wit-

*An address delivered before the Southern Commercial Congress at Atlanta, Georgia, March, 1911.

ness, will be known as the Age of Electricity. First the toy, and long the mystery of the scientist, electric power is now a familiar tool for the accomplishment of the work and the increase of the comfort and pleasure of mankind.

Although we may not know the ultimate nature of electricity, yet we do know some of its essential laws and methods of controlling and using it

During the twenty-five years in which I have been intimately interested in the electrical art, a development has been witnessed which has surpassed the most optimistic predictions. At the beginning of this period it was the general conviction that electricity would be limited to local use in the lighting of densely populated districts or the supply of power to adjacent factories. Indeed, there had been no developments to remotely foreshadow what has since been accomplished.

A Simple but Great Invention—At that period, however, there had already been developed and operated electric arc lighting circuits of high voltage, extended over rather large areas, with the pressure upon the wires of from 2 000 to 7 000 volts, which practically demonstrated that considerable electric power could be cheaply transmitted if means could be found to utilize safely high-voltage electric current for power and light and for other purposes; but such means were not then known. It often happens, when something is greatly needed for any great purpose, that as a result of a lively appreciation by many of the existing need, there arises in due course invention or discovery which meets the demand, and so it was in the matter of invention and discovery which gave us a simple static device, consisting of two coils of copper wire surrounded by sheets of iron, which could, without an appreciable loss of energy, transform alternating electric currents of high voltage and small quantity, dangerous to life, into low-voltage currents of large quantity, safely available for all power, light, heat and other purposes.

To the part I took in bringing forward in the '80s of the last century the *alternating-current system* of electric generation and distribution, I owe much, if not all, of the reputation accorded to me as one of the many pioneers in what is now a great and important industry.

When Restrictive Laws Would Have Defeated Progress—The introduction of alternating-current apparatus was bitterly opposed by those who were then exploiting direct-current apparatus,

and legislation was sought to prohibit its use because of its alleged danger to life. I mention this incident because it clearly shows that *restrictive* laws are not always advantageous, for had the legislation sought for by the opponents of the alternating-current system been secured and enforced, I would not now have any justification for this adddress, because the influence of electricity in the development of the South would be too unimportant to entitle it to consideration on this occasion.

Electric Power Carried Over 200 Miles—As a result of the development of the alternating current and of years of experience in the manufacture of electric transformers and of insulators for supporting electric conductors, power is now successfully transmitted by alternating current over distances of two hundred miles or more. Thus water-power in almost inaccessible places awaits only the coming of engineers and of capital to be made available for industrial purposes.

It is estimated by those who have made a study of the sources of water-power of the Appalachian mountains, that there can ultimately be developed from 5 000 000 to 7 000 000 horse-power during the dry season of the year, and a much larger quantity at other times. This great water power is brought by Nature to your mountains and hills in widely varying quantities and will continue indefinitely; but the maximum and minimum flow of the waters of your rivers can be affected by the works of man and by a wise conservation of your forests.

Electricity to Do the World's Work—Notwithstanding our familiarity with the present uses of electricity, few of us really comprehend how universal and fundamental is the part which electricity is destined to assume in the life of future generations. Nothing else can convey, distribute and apply power in a way which compares with electricity. From one dynamo can be taken the power for operating the telephone and the telegraph, the power for lighting, the power for operating street cars and railroad trains, the power for operating mills and factories and mines, the power for electro-chemistry, the power for heating. Electricity is a universal means of applying power for doing the physical work of the world. It is effective, not only in the application, but in the production of power. Less coal is required for producing electric power on a large scale than is required when many individual engines of smaller size are used. Water powers which otherwise would be unavailable are made useful for supplying power to dis-

tant cities, and even a mill located at a water power will give better service when it uses the electric drive. Electricity affords a simpler, better way of doing many things with which we are familiar, and it also makes possible new methods and new developments which, without it, would be impossible.

With electric power the mill can draw its energy from any stream within a radius of a hundred miles or more; it may be located on high and healthful ground, on the outskirts of an established town or city where labor is plentiful and transportation facilities are the best. In the plan and design of the mill itself, there is no longer the necessity of arranging buildings and machinery to be operated from great belts and long shafting taking power from a single source; but individual motors in each department, or on each machine or loom, enable the whole plant to be laid out so as to give economy in construction, convenience in handling materials, and ensure the safety and health of employees, thus securing a freedom and an excellence which is impossible without electricity.

The oppressive heat of the summer months in the South can be made tolerable by cooling devices and fans operated by electricity, and electric heaters, which are always ready for instantaneous service, can be used during the short intervals in the winter when artificial heat is necessary for comfort or health.

Conservation of Coal Resources—Furthermore, the use of electricity will conserve the coal deposits of the world for those industrial processes in the performance of which it may always be an indispensable element. To illustrate what a conservator of the coal resources of the country water power may prove, I will only mention that to produce for ten hours each day from coal the five million horse-power which may be developed from Southern water-powers, would require, with the most efficient kinds of engines, not less than twenty-five million tons of coal annually. If there were no water-power available, methods would be adopted for producing power and conserving heat, which would effect a saving of over one-half of the coal now consumed in the world. Here is a field for agitation against waste of our natural resources surpassing all others in importance.

THE SOUTH'S OPPORTUNITY

Now, what is the significance to the South of these facts? How can the South, which has almost everything before it in the matter of industrial affairs requiring the aid of modern achieve-

ment, by foresight and by promptly grasping the opportunities which are presented to it, hasten its industrial development, increase its wealth, improve the health of its people and increase their happiness?

Truly, here are subjects not to be circumscribed by the wisdom and judgment of one man, but calling for the united counsel and effort of the wisest and best among us—requiring not merely the knowledge of the scientist, the skill of the engineer and the wealth of the capitalist, but also the broad view, the enlightened experience and the high endeavor of our greatest statesmen.

Present Achievements in the South—In the development and utilization of the energy of waterfalls, the South has already taken a leading position, and the industrial benefits thereof are so widely and favorably known that no argument is now needed to justify the work already done or to point out the great and lasting benefits to be derived from its extension.

Any address on electricity in the South would be incomplete without an expression of high appreciation of the work of the Southern Power Company, begun by Dr. Wylie and developed to its present stage by the Messrs. Duke.

A Great Electrical System—This is the largest power transmission system in the South and is among the most extensive and important in the country. It is not a simple transmission line from a single power house to a single mill or city, but an extensive system which receives power from many power plants on different streams in several States. Hence low-water or high-water on one river, which might temporarily disable certain plants, has but a slight effect on the whole system.

The lines of the Southern Power Company extend 150 miles north and south and 200 miles east and west, and connect into a single hydro-electric power system plants aggregating 100 000 horsepower. It is a magnificent demonstration of what electricity can do to conserve and utilize water power in developing the great and growing textile and other industries of the South. The Southern Power Company is furnishing light to forty-five cities and towns and supplying current to six street railway systems and to hundreds of motors for various uses. This power development is the result of intelligent and far-sighted business courage and confidence in Southern affairs, which have inspired and actuated the men who have built up this great enterprise.

I am informed that the millions already invested in the Southern Power Company have not yet yielded even a moderate net in-

come to those who have put their money into an investment which has benefited others more than themselves by insuring an increase in production and profit to its patrons, a striking evidence of the importance of a generous treatment by authorities as well as by those who derive an absolute money benefit.

Industries Likely to be Developed—The industries most likely to be developed and to increase because of peculiar suitability to conditions now existing in the South are:—Textile mills, fertilizer works, cement plants, coal, iron, copper and gold mining, ore reduction plants, iron and steel mills, agricultural implement works, canning factories, road building, furniture manufacture, lumber plants, paper mills, shoe and leather factories, and oil refineries, in all of which industries electric power increases production.

Electricity in Metallurgy—The South abounds in coal and iron as well as other metals, which can be cheaply mined. Owing to the presence of impurities in the iron ore, especially phosphorus, the pig irons produced in the South have not been considered so suitable for steel manufacture as those made from the purer ores of the North. The electric furnaces for refining steel, which have been recently developed and quite extensively used, will make available the iron resources of the South in the production of the high grades of steel, and it is no stretch of imagination to foresee that the South will become a large producer of the raw material, and through the cheapness of its labor it will be able to turn these materials into finished products. At the same time the slag by-product of blast furnaces will remain to be used for fertilizing purposes.

Electrical Production of Fertilizers—The South is already a large user of fertilizers, much of which is imported and the supply of which is limited and exhaustible, nitrogen forming an important part of the fertilizers which are commonly used. During the past few years great attention has been given to the development of means for the electric production of fertilizers and so much has already been accomplished that it may be said with confidence that the fertilization of our soil within the near future will be largely dependent upon electricity. Most of the material required, coal and limestone, for this purpose, is found in the South in unlimited quantities. Were the soils in the United States as carefully tilled and fertilized as in many densely populated countries, there would be an immense increase in our agricultural products.

Electricity in Cotton Mills—A brief consideration of the special advantages already derived from the use of electric power in

the cotton industry will well illustrate the benefits to be gained from the general extension in the use of this wonderful force to other fields.

The output of cotton mills has been increased and the quality of goods is improved, due largely to the uniform speed attained by the electric drive compared with power conveyed through belts and lines of shafting. This uniform speed has resulted in an increased production with an increased profit, which in some cases exceeds the cost of the electric power. With electric drives, recording meters can be placed in the circuits which supply power, and the instantaneous power or the total power for any given time can thus be ascertained, a feature of great value to the management in determining whether separate departments of the mill are starting or stopping on time and whether the full load is kept on the machines during working hours.

With electric drives, one set of machines or a part of a mill can be independently operated when it is not advantageous or convenient to run the whole mill. When there is a single power house with mechanical drive, any enlargement must be conditioned upon the extension of shafting or belting; but with electricity, wires can be readily run to any point in the old buildings or to new buildings.

In the territory of the Southern Power Company, it was at first difficult to induce the mill managers to adopt electric power, and it took three years of effort to introduce ten thousand horse-power; then, however, mill managers observed the advantages of their neighbors who used electric power, with the result that at the end of the next period of three years electric power had increased to more than 65 000 horse-power, while now there is a total of 80 000 horse-power of electrical machinery installed.

Of the 300 or more cotton mills in North Carolina, about 25 percent are now wholly driven electrically. Although there has been a great increase in the number of cotton mills in the South in recent years, the mills have been devoted to the production of the cheaper grades of cloth; but it is predicted that the future growth will not be merely in the number of mills, but will be in the production of the finer grades of cotton fabrics.

In Transportation—I have briefly sketched the fundamental place which electric power distribution is taking in industrial activities, and I have briefly referred to what one electric power transmission company is accomplishing in pushing the textile industry in which the South takes just pride. Time does not permit

me to catalogue all the possibilities of electricity in the development of this great country. The South has mineral resources to be developed—electricity is the established method for mining operations. The main railway lines of the South run north and south—electricity enables trolley lines to be run east and west to serve as feeders for the trunk lines, and when electricity is used for the operation of your railways, as it will certainly be some day, there will follow a more intimate relationship between producers and carriers than might otherwise exist.

LOOKING FORWARD

Having been asked to speak upon the subject of electricity in the development of the South because of my connection with the electrical industries of the country, it seems to me I cannot fulfill the expectations of those who have planned this Congress by limiting my observations to matters with which you are more or less familiar from personal experience or from articles in your daily papers and in magazines; I should also ask you to look forward to what we may expect in the years to come.

Electricity in Agriculture and Horticulture—In 1906-7 some experiments were made in England with the coöperation of Sir Oliver Lodge, the eminent English scientist, in the stimulation of plant growth by electricity. It has been frequently observed that plant growth is stimulated by electric light, and numerous experiments have been made having for their object the stimulation of the soil by the application of electric current. The experiments reported by Sir Oliver Lodge in a privately printed brochure on Electricity in Agriculture are briefly as follows:—

Two tracts of land about twenty acres each were similarly sown or planted. On half of this land poles with insulators were erected to support the electric wires, only one pole per acre being required for the purpose. The electricity required was produced by a small dynamo driven by a two horse-power oil engine and was transformed to a tension of about 100 000 volts of very high frequency. The experiments, which extended over several years, give remarkable results, an increase of from 30 to 40 percent being secured in wheat crops grown on the electrified plot as compared with the crop produced on the unelectrified plot. Moreover, the electrified wheat was of a better milling and baking quality and sold at a considerably higher price than that grown on the unelectrified plot. Similar experiments with strawberries, man-

golds, tomatoes, cucumbers, beets and carrots showed equally remarkable results. One-year strawberry plants showed in one instance 80 percent increase and more runners produced, while with five-year plants the increase was 36 percent.

In writing to me on this subject in response to my request, in order that I might make a reference to it in this address, Sir Oliver Lodge suggested that the results attained in the experiments referred to and in others would justify an elaborate series of experiments. These experiments could be usefully undertaken at the stations under the control of the Agricultural Department.

An explanation given for the excitation of vegetation by these high tension currents is that high frequency electrical discharges favorably affect the deposit of the nitrogen in the atmosphere into the soil, upon which deposit vegetation so largely subsists.

Whatever prevents disease and ensures health contributes not only to man's happiness, but also to his efficiency, and it appears that the electric current is to play a very important part in this field.

Mercury Vapor Lamps—Ultra-Violet Rays—The outcome of the efforts of one who specializes in any particular kind of apparatus is often interesting. The development, by Doctor Peter Cooper Hewitt, of the mercury vapor lamp, has provided a light which is the least fatiguing to the human eye of all artificial lights, and experimentation with this lamp has led to the development of several other uses of the mercury vapor arc, one of which is the production in quartz tubes of ultra-violet rays, the effects of which are likely to be of the very highest importance in our daily lives. While these ultra-violet rays are emitted in the quartz tubes, they are effectively neutralized by the glass tubes which contain the mercury vapor used in lighting.

Sterilizing Water and Milk—One of the important uses to which these ultra-violet rays have already been put has been to absolutely sterilize water, however much it may have been contaminated by bacteria. Experiments have also shown that the ultra-violet rays will sterilize milk without the application of heat in such a manner that it can be kept in properly sterilized vessels for long periods without deterioration or loss of its food values.

With the growth of population, the pollution of rivers, and the contamination of the water supply upon which our population must rely, and the difficulty of determining whether the water and milk we use are free from noxious bacteria, this safe and thorough method of sterilization becomes of inestimable value. The elaborate

experiments and demonstrations which have already been made at the Sorbonne, in Paris, and at the City Water Work of Marseilles, France, have not only proved the feasibility of this method of sterilization, but have brought out the fact that a 15 000 kilowatt generator of electrical energy could sterilized, by means of mercury vapor quartz lamps, as much water as is actually used for drinking and cooking in the United States.

The simplicity of the apparatus for sterilizing water is such that there is no doubt but that it can be advantageously installed in factories and other places, and even in dwellings, adjacent to the point or points where the water is to be used, thus avoiding any possible contamination between the point of supply and point of use.

The electric energy required for the operation of a quartz mercury vapor lamp used for the daily sterilization of 85 000 gallons of water is about equal to that required for half a dozen ordinary incandescent lamps.

Ageing of Wine—Not only have water and milk been sterilized, but in other experiments, also carried on at the Sorbonne, it was found that new wine was affected in a manner to give it the qualities normally attained in years, or an age of apparently many years was given by a few second's application of the ultra-violet rays.

These experiments and investigations suggest that uses for the ultra-violet rays will be found which have not yet been conceived.

Supplanting Costly Apparatus—An important use of the mercury vapor apparatus has been to transform or rectify alternating currents into continuous currents, and some recent experiments indicate that this can be done on a large scale with a considerable saving of electrical energy. These promising results foreshadow the disappearance of the costly rotating apparatus which is now used for that purpose in the operation of railways and for purposes where the use of a continuous current is advantageous.

Hertzian Waves—The transmission of electrical energy through the atmosphere without wires has, in a very few years, so far advanced that wireless telegraphy is now an important feature of our daily life. We read of instances where wireless messages have been received at a distance of over three thousand miles from the point at which they were sent, and it is said that we shall shortly have regular wireless communication between Paris and New York.

Portable Wireless Telephones—Not only has it been possible to communicate by wireless in the Morse code, but it has been found that, with suitable apparatus, telephone conversations can be carried on over considerable distances, and it is expected that by improvement in the apparatus, conversations can be carried on over very considerable distances. Investigations, of which there is almost daily mention in the public press, indicate such great simplification in wireless telephone apparatus that we may, within the quite near future, have placed at our disposal a simple portable apparatus which will permit wireless conversation to be carried on over a considerable area. This will prove of great value in sparsely settled districts.

Possibilities of Hertzian Waves—It may interest you to know that the frequency of the electrical waves sent out by some forms of wireless transmitters approaches a million per second, and that by either an increase in the amplitude of these vibrations or by a more sensitive receiver, the distance over which these waves (which undoubtedly extend to an infinite distance) may be recorded, can be greatly increased.

In an experiment made by Doctor Peter Cooper Hewitt with powerful wireless transmission apparatus, including a mercury vapor interrupter, it was found that the effect of the high-frequency discharge upon the iron in the building occupied, such as water and heater pipes, quickly produced incipient fires within the room where the apparatus was erected, thus demonstrating the wonderful power of this incomprehensible force and suggesting great possibilities in the transmission of electrical energy without wires.

The transmission of electric energy without wires which will be especially valuable for signalling purposes and for the control of machinery at a distance, will undoubtedly play a most important part in army and navy operations.

Lord Kelvin on Radium—We are hearing and learning more and more in regard to the power of radium, and predictions have been made that it will some day furnish power in great quantities. This I very much doubt. The popular belief is that radium constantly produces heat and light without an appreciable loss in its weight, and that it will continuously produce heat. Lord Kelvin, whom I had the honor of knowing, was greatly interested in the discovery of radium by Madame Curie. In one of the last conversations I had with him, I ventured to give a conception of the cause of the "production" of heat by radium, my

idea being that radium acts as a transformer of one of the forces of ether into some other form of force, and that in such transformation heat is produced. Lord Kelvin, who had studied the subject, said that he had already arrived at the same conclusion on the general hypothesis that neither heat nor light can be produced without energy. I refer to this because of the indication that there exists a form of energy of which we have as yet no knowledge, but which may yet become available to us as a result of further discoveries.

COÖPERATION SHOULD BE COMPULSORY

The advantages of coöperation in the matter of the development and supply of electricity, having regard to a lessening of the cost and insuring the certainty of supply, cannot be overestimated, and those already secured by operations on a large scale are well known. Further coöperation in this great work for the benefit of the public, if not voluntary in the future, should, in my opinion, be an enforced one, notwithstanding the outcry which has been raised by the ill-informed with reference to an imaginary monopolization of the water-power of the nation. Encouragement should be given to the investment of capital in the development of these enterprises under such wise and reasonable regulation as will insure economy in the construction and operation of plants, adequate returns to the capital invested, and at the same time protect the consumer against exorbitant rates and charges or unfair discrimination.

In the larger industrial developments which I foresee for the South there are other important factors which equal in importance the development of the water-power resources upon which I have dwelt. I have particularly in mind those existing restrictions which make it difficult and expensive for a small corporation to carry on conveniently and in a simple manner its business with ramifications in several States, which restrictions, however, the great corporations of the country can easily surmount by reason of their financial ability to organize separate subsidiary companies in those States where such an expedient is rendered necessary to meet legislative requirements.

FEDERAL INCORPORATION

I have long held that a Federal Incorporation Act, which the President advocates, under which all companies doing an interstate business could organize, would be a solution of the difficulties which are now almost insurmountable, and which are being added

to in an alarming manner in the endeavor of the legislatures of the several States to curb a few of the tens of thousands of companies and firms doing an interstate business.

Protection of Minority Owners—After having read and carefully studied the bill providing for Federal incorporation, which was introduced in the long session of the present Congress, I am constrained to say I would prefer to see a Federal law in terms more easily comprehended by business men and devoid of those provisions which would give to a privileged few a practical control of a corporation by expedients which have been skilfully developed and which are now looked upon as a matter of course.

I have in mind particularly the depriving of minority owners of possible representation by the formation of voting trusts and the election of directors in classes, methods which can, and often do, defeat the purposes of laws which have provided for cumulative voting, whereby a substantial minority can insure the election of at least one member of a board of directors.

Directors Should Be Large Shareholders and Elected Annually—In my judgment, each director of a corporation should be required actually to own a substantial interest in the shares of the company, the affairs of which he aids to control, and the term of office be only from year to year. To make my meaning clearer, I will illustrate by supposing that a company had, by appropriate by-laws, established a board of five directors, only one of whom could be elected each year. Obviously, the provision of the law for cumulative voting would have no meaning in the government of the affairs of such a company.

It may be unorthodox to say this, but it is my conviction that the conduct of a business without profit is disadvantageous to the community at large because of its demoralizing effect on the industry and its influence upon others. A Federal Incorporation Act should provide for a statement, on prescribed forms, of the assets and liabilities of each corporation taking advantage of its provisions. This statement should be available to all who are asked to extend credit to the corporation. The disadvantage to a company of doing business at a loss under such conditions need not be enlarged upon.

Each of the great corporations of to-day had its origin in a business established by an individual or small company based upon the skill and efforts of one or more individuals. The development of the South must be more or less rapid according as the work of

such men is appreciated and encouraged, especially during the period of strenuous effort necessary to the building up of large and prosperous industries from small beginnings.

THE TRAINING OF YOUNG MEN

In conclusion, I urge the young men of the South to make themselves familiar with industrial affairs by learning to be proficient in the use of their hands as well as in the use of their heads. My early greatest capital was the experience and skill acquired from the opportunity given me when I was young to work with all kinds of machinery, coupled later with lessons in that discipline to which a soldier is required to submit, and the acquirement of a spirit of readiness to carry out the instructions of superiors. President Taft's statement that the introduction of military discipline in the schools and colleges of the land, in the advantages of which all would participate, would be of greater benefit to our country than the high development of athletics by a few, is worthy of most serious attention. The present preëminence of Germany in industrial matters arises very largely from the military training and discipline to which each of her citizens must submit.

THE SOUTHERN POWER COMPANY'S SYSTEM

L. A. MAGRAW

GOVERNOR JOHN BRAYTON, in 1802, published a small volume entitled "A View of South Carolina as Regards Her Natural and Civil Concerns," in which he described "The Great Falls of Chester" on the Catawba River, stating that for quantity of water and grandeur of appearance they are without doubt the most interesting in the State. "From a width of one hundred and eighty yards the channel of the river narrows to sixty yards. In a distance of two and one-half miles the water leaps twenty falls and is precipitated a total height of one hundred and fifty feet."

At the time of that writing, however, the power developed from the harnessing of energy in this form had no market and, as

VIEW OF DAM AT CATAWBA GENERATING STATION

the river was navigable both above and below the falls, the State naturally wished for commercial reasons that the falls were not there, so in 1824 the construction of a canal was begun, which was completed in the early thirties at a cost to the State of $300 000. It was hoped that by enabling boats to pass the falls, navigation of the river would be opened to the foot of the Allegheny Mountains. Only two boats ever passed through this canal, and to-day the walls and locks of cut stone, after eighty years of weathering, have changed little in appearance. The skill with which the stone was cut, especially at the spillways and locks, is worthy of special note.

Local tradition is that Great Falls came within one vote of being the military academy of the United States. Those so inclined

may speculate as to the effect on our history, if a great military academy with all the attendant patronage and influence had been established on the banks of the Catawba like that on the Hudson.

As early as 1732, a trading post was maintained at Mountain Island by the British Government and, previous to 1803, the United States Government ordered that a permanent arsenal and magazine be established here for the States of North and South Carolina and Georgia. In 1803 Eli Whitney, assisted by Col. Seul, chose a site on Mountain Island, and during the years of 1803 and 1804, an armory, arsenal, officers' quarters and barracks were erected here and called Fort Dearborn. The fort was abandoned in 1817 and the troops were withdrawn.

GREAT FALLS POWER HOUSE

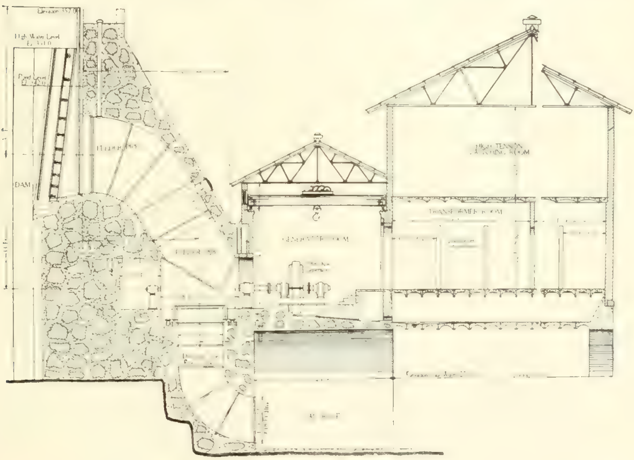
DEVELOPMENT OF POWER

Benson J. Lossing, writing in 1859, says of Great Falls, "At this place, in the midst of fine cotton-growing country, almost inexhaustible water power invites capital and enterprise to seek good investment and confer substantial benefit upon the State." To-day we find the surrounding Piedmont district in an active stage of development through the utilization of its natural resources. The generation of hydro-electric power has increased in some eight years from a single station of 6 600 kilowatts capacity to an immense system of interconnected stations having a present aggregate capacity of 100 000 kilowatts, from which radiate high-tension transmission lines the longest of which is over 200 miles, forming a network of over 1 300 miles of line. Yet it is estimated that but 10 percent of the water power available in this territory is utilized by the hydro-

electric development thus far completed. Thus, the future of the Southern Power Company which is responsible for the work already done and which holds the power rights for subsequent development is evidently most promising.

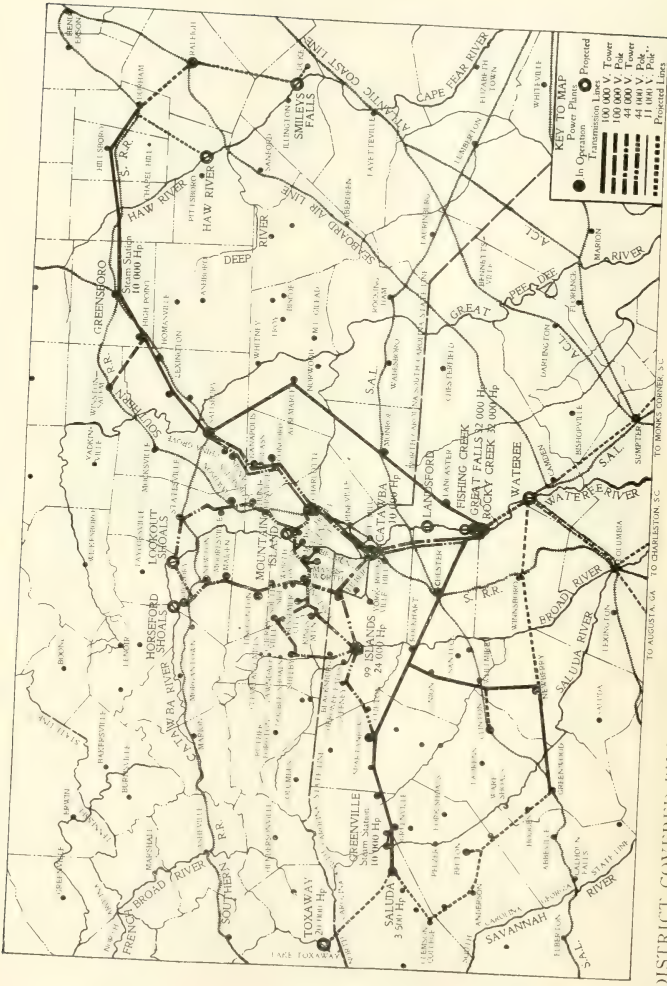
CATAWBA GENERATING STATION

In the Spring of 1904 the Catawba Power Company completed a hydro-electric plant at India Hook Shoals, near Rockhill, South Carolina, and thirty-three miles from Great Falls on the Catawba River. This plant consists of four 750 and four 900 kw, 60 cycle,



CROSS SECTION THROUGH BULKHEAD AND POWER HOUSE, GREAT FALLS STATION
Showing racks, gates, intake and tunnel for inner turbine bearing

11 000 volt generators, driven by means of ropes from the water turbines. Power is transmitted over 11 000 volt lines, the total length of which at the present time is sixty-five miles. A switching station was later added to this installation, containing three 2 000 kw, 11 000/50 000 volt transformers to tie into the 50 000 volt system. The purpose of this station was to supply power to the cotton mills in the immediate vicinity of Rock Hill, South Carolina, but it was only after the hardest kind of pioneer work, without the slightest encouragement from the mill owners, that electricity was introduced as a means of driving cotton mills. However, by the Spring of 1905 the demand for electric power had so grown that



DISTRICT COVERED BY THE TRANSMISSION SYSTEM OF THE SOUTHERN POWER COMPANY
Showing present and projected transmission lines.

TRANSMISSION LINE AND SUB-STATION DATA

100 000 VOLTS

GREAT FALLS TO SALISBURY

Twin tower line, 95 miles, 2 circuits: No. 00 equivalent aluminum stranded and No. 00 stranded copper. Salisbury has 6 - 2 000 kw, and 3 - 1 000 kw transformers.

Taps: Lancaster, 13 miles out, 3 - 1 000 kw transformers; Monroe, 37 miles out, 3 - 1 000 kw transformers; Albemarle, 70 miles out, 3 - 1 000 kw transformers.

SALISBURY TO GREENSBORO

Twin tower line, 49 miles, 2 circuits: No. 00 equiv. al. strnd. and No. 00 strnd. copper. Greensboro has 3 - 1 000 kw transformers.

Taps: Lexington, 16 miles out, 3 - 1 000 kw transformers; Thomasville, 27 miles out, 3 - 1 000 kw transformers; High Point, 33 miles out, 3 - 1 000 kw transformers; Winston-Salem, from junction to main line, pole line, 18 miles, 1 circuit: No. 2 equiv. strnd. al.; 3 - 150 kw, 3 - 200 kw, 3 - 500 kw, and 3 - 1 000 kw transformers.

GREAT FALLS TO GREENVILLE

Twin tower line, 96 miles, 2 circuits: No. 00 copper strnd. and No. 00 equiv. al. strnd. Greenville has 3 - 3 000 kw transformers.

Taps: Chester, 21 miles out, 3 - 1 000 kw transformers; Spartanburg, 66 miles out, 3 - 2 000 kw transformers; Greer, 84 miles out, 3 - 1 000 kw transformers.

GREENVILLE TO EASLEY

Twin tower line, 12 miles, 1 circuit: No. 00 equiv. al. strnd. Easley has 3 - 1 000 kw transformers.

50 000 VOLTS

ROCKY CREEK TO GREAT FALLS

Twin tower and poles lines, 3 miles, 3 circuits: two on twin tower, each No. 0000 equivalent aluminum stranded; one on pole, No. 00 equivalent aluminum stranded.

GREAT FALLS TO CATAWBA

Twin tower and pole lines, 33 miles, 3 circuits: two on twin tower, each No. 000 strnd copper; one on pole, No. 000 equiv. al. strnd. These lines normally dead-end at Catawba switching station with 3 - 2 000 kw, 11 000 44 000 volt tie-in transformers.

CATAWBA TO CHARLOTTE

City steel towers through Charlotte, remainder double pole line, 18 miles, 2 circuits: each No. 00 equiv. al. strnd. Transformers in Charlotte: 3 - 200, 3 - 300, 3 - 500, 3 - 750, and 9 - 1 000 kw.

CHARLOTTE TO CONCORD

Pole lines, 22 miles, 2 circuits: No. 00 and No. 2 solid copper. Concord has 6 - 1 000 kw transformers.

CONCORD TO SALISBURY

Pole lines, 23 miles, 2 circuits: No. 00 and No. 2 solid copper. This line continues to Salisbury tie-in station.

Taps: Kanapolis, 7 miles from Concord, 3 - 1 000 kw; China Grove, 14 miles from Concord, 3 - 200 kw transformers.

CATAWBA TO GASTONIA

Twin tower line, 32 miles, 2 circuits: No. 00 equiv. strnd. al. and No. 00 strnd. copper. Gastonia has 3 - 200 and 3 - 1 000 kw transformers.

GASTONIA TO MOORESVILLE

Pole line, 35 miles, 1 circuit: No. 2 solid copper. Mooresville has 3 - 500 kw transformers.

Taps: Lowell, 3 miles out, 3 - 300 kw transformers; Mayesworth, 4 miles out, 3 - 300 kw transformers; McAdensville, 5 miles out, 3 - 150 kw transformers; Belmont, 9 miles out, 3 - 300 and 3 - 250 kw transformers; Mt. Holly, 11 miles out, 3 - 200 kw transformers; Davidson, 28 miles out,

MOORESVILLE TO STATESVILLE

Pole line, 17 miles, 1 circuit: No. 4 solid copper. Statesville has 3 - 500 kw transformers.

GASTONIA TO BESSEMER CITY

Pole line, 7 miles, 1 circuit: No. 2 solid copper. Bessemer City has 3 - 300 kw transformers.

BESSEMER CITY TO KINGS MOUNTAIN

Pole line, 5 miles, 1 circuit: No. 2 solid copper. Kings Mountain has 3 - 1 000 kw transformers.

BESSEMER CITY TO SHELBY

Pole line, 16 miles, 1 circuit: No. 4 solid copper. Shelby has 3 - 300 kw transformers.

Tap: Cherryville, 9 miles out, 3 - 300 kw transformers.

NINETY-NINE ISLANDS TO SHELBY

Pole line, 19 miles, 1 circuit: No. 00 equiv. al. strnd.

NINETY-NINE ISLANDS TO CLOVER

Pole line, 18 miles, 1 circuit: No. 00 equiv. al. strnd.

NINETY-NINE ISLANDS TO SPARTANBURG

Pole line, 29 miles, 1 circuit: No. 00 equiv. al. strnd.

GASTONIA TO LINCOLNTON

Pole line, 16 miles, 1 circuit: No. 00 strnd. copper. Lincolnton has 3 - 500 kw transformers.

Taps: Dallas, 4 miles out, 3 - 100 kw transformers; High Shoals, 11 miles out, 2 - 100 kw transformers connected in V.

LINCOLNTON TO HICKORY

Pole line, 28 miles, 1 circuit: No. 4 solid copper. Hickory has 3 - 500 kw transformers.

Taps: Maiden, 8.5 miles out, 3 - 300 kw transformers; Newton, 15.5 miles out, 3 - 200 kw transformers.

SPURIER JUNCTION TO CHARLOTTE

Pole line, 9.5 miles, 1 circuit: No. 00 equiv. al. strnd.

11 000 VOLTS

CATAWBA TO PINEVILLE

Pole, line, 8 miles, 1 circuit: No. 2 equivalent aluminum stranded. Pineville has 3 - 37.5 and 3 - 125 kw transformers.

CATAWBA TO FT. MILL

Pole line, 6 miles, 1 circuit: No. 2 equiv. al. strnd. Ft. Mill has 3 - 100 and 4 - 100 kw transformers.

CATAWBA TO CLOVER

Pole line, 23 miles, 1 circuit: No. 00 solid copper. Clover has 3 - 125 and 3 - 200 kw transformers.

Tap: Yorkville, 15 miles out, 3 - 100, 3 - 125, and 3 - 300 kw transformers.

CATAWBA TO ROCK HILL

Pole line, 7 miles, 2 circuits: each No. 1 solid copper. Rock Hill has 3 - 25, 4 - 50, 3 - 100, 6 - 125, 6 - 150, 3 - 200, 3 - 250, 3 - 300, and 3 - 500 kw transformers.

the Catawba Power Company formed a larger organization, the Southern Power Company, for the purpose of supplying energy to mills within commercial transmitting distance of certain water powers on the Catawba and Broad Rivers, which could be developed within a reasonable cost.

GREAT FALLS GENERATING STATION

In November, 1905, the construction work of the Great Falls power house was begun; it was completed March, 1907, with current on the lines April 2nd. The hydraulic layout of this power house is worthy of special note. There are two concrete diverting

INTERIOR OF GENERATOR ROOM, GREAT FALLS STATION

dams with spillways which guide the water into the canal. The bulkhead at the power house has no spillway; it is of concrete 650 feet long and a maximum of 105 feet high. The canal leading to the forebay is a natural channel between Mountain Island and the mainland. The main bed of the river in which the spillways are located is on the other side of the island, over a mile distant from the power house.

The power house contains eight 5 200 horse-power, horizontal twin turbines operating under a 72 foot head, each coupled to a 3 000 kw, 60 cycle, 2 200 volt, 225 r.p.m., star-connected generator, and twelve 2 000 kw, single-phase, oil insulated, water cooled transformers, delta-connected on the high and low tension sides, and

arranged in four banks, with a normal ratio of 2 500 to 50 000 volts. There are two 400 kw, 250 volt exciters operating at 450 r.p.m., each of which is sufficient to provide excitation for all the generators in the power house. Each exciter is driven by its own turbine. The power house has been described in detail in a previous issue,* but there are many points in the lay-out of the apparatus and the station which deserve particular mention. The generators are arranged in groups of two, so that together they can feed one bank of transformers operating at full load, but the switching arrangements are so flexible that any bank of transformers can be fed from any generator through the bus sectionalizing switches, and on the high-tension side, similar switches make it possible to feed any outgoing line from any transformer bank. In short, the power house is divided into four parts of equal capacity, each complete in itself—if the exciters be excepted—but so arranged that any required combination of generators, transformers and feeders can be effected.

SWITCHBOARD, PART OF INSTRUMENT POSTS, AND GENERATOR CONTROL PEDESTALS
Great Falls Station.

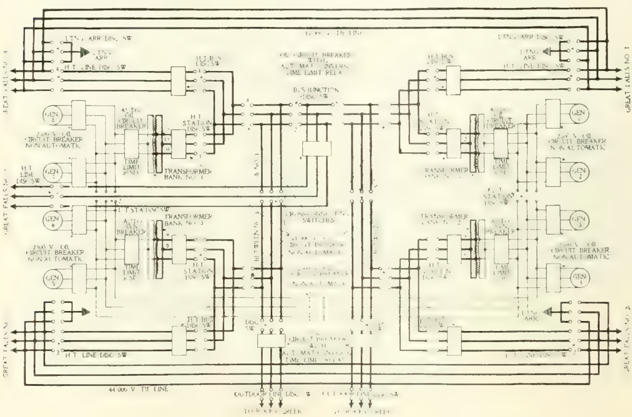
The exciters can be connected to either of a double set of bus-bars. The generator field switches are so designed that the fields can be changed from one set of bus-bars to another without opening the circuit. Non-automatic bus junction switches divide the power house on both the high-tension and low-tension sides into two halves, and one generator in each half has its neutral grounded through a resistance of 1.5 ohms of sufficient capacity to carry 1 000 amperes for one minute. This lead to ground passes through a non-automatic oil switch equipped with a relay for sounding a bell alarm whenever there is an abnormal current.

Disconnecting switches are used in connection with all oil circuit breakers and oil switches so that they can be cut out for inspection. All control apparatus is operated from the 250 volt exciter bus-bars, no storage battery being used. There is no so-called

*See the article by Mr. L. T. Peck on "The Great Falls Power Plant of the Southern Power Company" in the Journal for Dec., 1907, p. 666.

operating gallery, but instead a raised platform, three feet, nine inches above the floor level and six feet wide, extends two-thirds the length of the generator house, describing an arc at its center, within which are located all instruments and the switchboard and control pedestals for the generators, and from which point the operator has full view of all machinery.

Four wheels are equipped with governors which take care of variations in the load; the other wheels run under constant load. Hydraulic cylinders for operating the gates are being installed on the wheels without governors to replace hand operation, so that the man at the switchboard can have absolute control over the gates without assistance from floor operators. The wheel cases as well



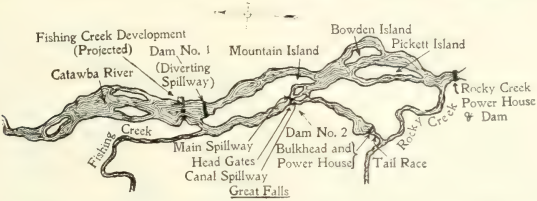
THEORETICAL WIRING DIAGRAM, GREAT FALLS STATION

as the steel feeder pipes are enclosed by the bulkhead wall; the short penstocks thus obtained are a decided advantage. No concrete barriers are used in the high-tension room, as the rule that air is cheaper than concrete has been followed, and the necessity for steel fire doors has been reduced to a minimum. Simplicity characterizes the design of this power house, but that nothing has been sacrificed for simplicity is demonstrated by over three years of very successful operation.

ROCKY CREEK GENERATING STATION

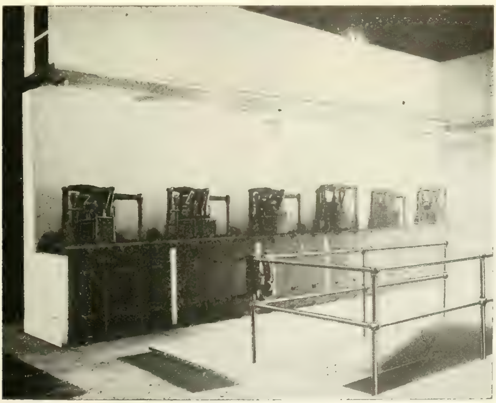
Three miles below Great Falls is Rocky Creek power house, located on the west bank of the river. The hydraulic arrangements

here are simpler, for there is but one concrete dam extending across the river with a length of 1 000 feet and a height of 90 feet. It is of the spillway type and holds back a pondage of about 1 000 acres. The work on this development began immediately after



SKETCH SHOWING RELATIVE POSITION OF GREAT FALLS, ROCKY CREEK, AND PROJECTED FISHING CREEK DEVELOPMENTS
In a distance of seven miles there is a total drop of 175 feet.

the completion of the Great Falls power house and was finished in 1909. The normal head here is 68 feet. The power house is an exact duplicate of that at Great Falls with the exception of the arrangement of the exciters. Here but one turbine driven exciter is used, and in line with it is a 600 hp, 60 cycle, three-phase, 2 200



LOW-TENSION SWITCHES AND BUS-BAR COMPARTMENTS
Showing one-half of this equipment.

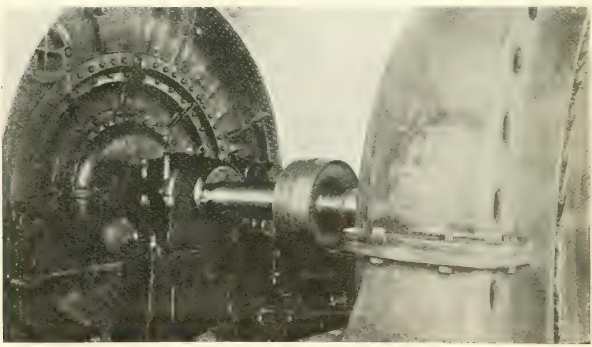
volt, 450 r.p.m. induction motor, coupled to a second exciter. Between the motor and the exciter driven by the water wheel is a friction clutch; thus the motor may be arranged to drive either exciter, or the water wheel can run the two units with the induction

motor dead in case of emergency. Either exciter is, of course, large enough to provide excitation for all of the alternating-current

GREAT FALLS 100 000 VOLT TIE-IN SUB-STATION
Tail race and part of Great Falls power house in background.

generators. The entire output of these two power houses is transmitted at 52 000 and 100 000 volts.

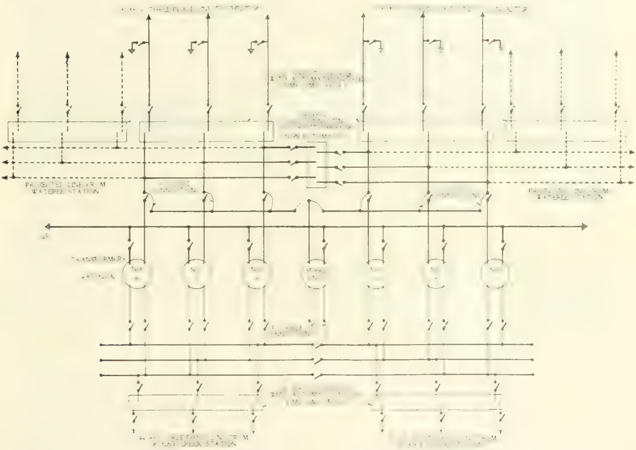
Three lines leave Rocky Creek power house each of which passes through oil insulated, self-cooled choke coils and is protected by electrolytic lightning arresters. Two of these lines are on a



WHEEL CASING AND COUPLING OF 5 200 HP HORIZONTAL TWIN TURBINE

steel twin tower and are of No. 0000 equivalent aluminum stranded cable, while the third line is on wooden poles and is of No. 00 equivalent aluminum stranded cable.

Great Falls Tie-In Sub-Station—During the latter part of 1907, in the face of increasing demand for electric power in places so distant that economical transmission at 50 000 volts was out of the question, it was found necessary to employ a higher voltage of transmission and 100 000 volts was decided upon. As the 50 000 volt lines were already well loaded, it was decided to build a 100 000 volt tie-in sub-station at Great Falls close to the generating station. This building was completed and placed in service December, 1909. It is of red pressed brick with stone trimmings; the roof is of concrete, tar and gravel. This station is located on the west side of the tail race of the generating station. It contains seven 4 000 kw.



WIRING DIAGRAM, GREAT FALLS TIE-IN SUB-STATION
Four circuits now leave this station.

single-phase, oil insulated, water cooled transformers with a normal ratio of 50 000 volts low-tension to 57 700 volts high-tension, arranged in two banks with one spare unit. These transformers are connected in delta on the low-tension side and star on the high-tension side and have been operating regularly with the neutral grounded through a resistance of 112 ohms, having a continuous carrying capacity of 130 amperes. They can be so connected as to operate at a maximum of 115 000 volts. There are house bus-bars on both the high and low-tension sides. The low-tension house bus-bars are separated into two parts by sectionalizing disconnecting switches, and on the high-tension side by a non-automatic bus junc-

tion oil switch. Each transformer is connected to its bus-bars through disconnecting switches on both high and low-tension sides and there are disconnecting switches on both sides of all oil circuit breakers in this sub-station.

ROCKY CREEK STATION
Spillway on the right and two banks of electrolytic lightning arresters in the foreground.

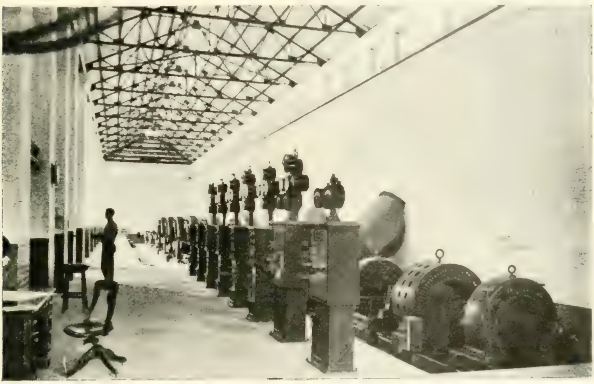
The transformer tanks are equipped with flanged wheels, which rest upon steel rails placed at such a height that the transformers can be run upon a truck, also mounted on rails. These rails run the entire length of the building at one end of which there is a

NINETY-NINE ISLANDS POWER HOUSE

lifting tower equipped with a crane. As the open type construction is used, there are no concrete barriers in the building, and the transformers are not placed in concrete compartments. Outlet wall bushings are used for the 100 000 volt lines and, in addition,

this sub-station is built with long, overhanging eaves, which act as hoods above the outlets.

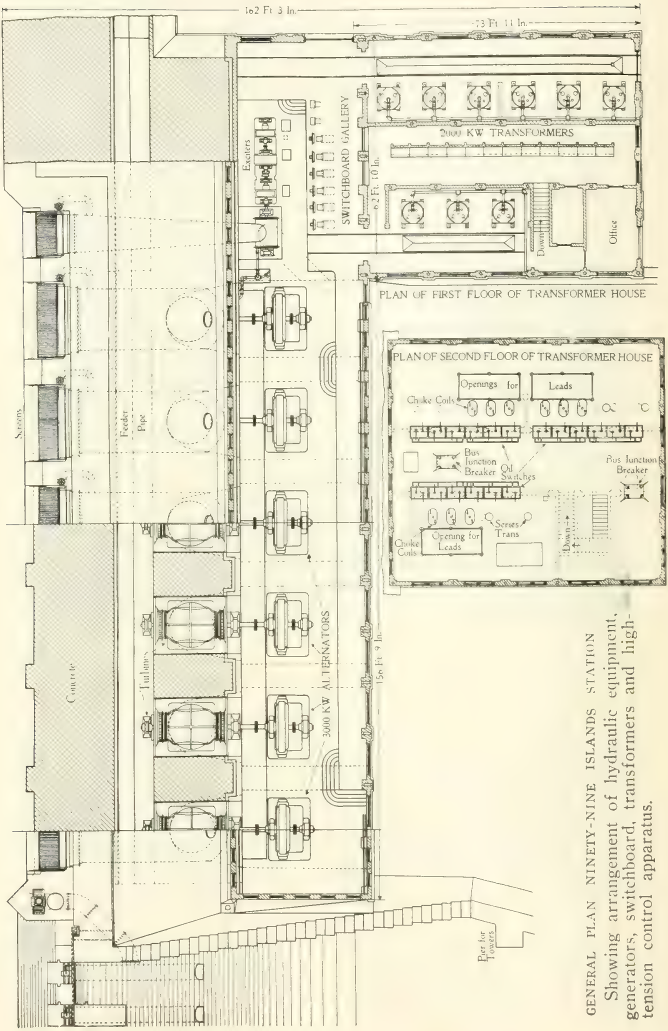
The wooden pole line from Rocky Creek, mentioned above, enters this sub-station through an oil circuit breaker, while one of the circuits on the twin tower line from Rocky Creek taps into the Great Falls generating station bus-bars and continues on into the sub-station through an oil circuit breaker. Both of these breakers, as well as all the circuit breakers and the bus-junction switch on the high-tension side of these transformers, are electrically operated from the switchboard in the Great Falls generating station. The third



VIEW IN NINETY-NINE ISLANDS STATION FROM OPERATING PLATFORM
Control pedestals and exciter set in foreground. Six 3 000 kw, 2 200 volt, 225 r.p.m., three-phase generators in background.

line coming from Rocky Creek dead-ends on the Great Falls generating bus-bars; thus it can be seen that Rocky Creek can take care of the 100 000 volt load independent of the Great Falls station. With no load on the 143 miles of line leaving the 100 000 volt sub-station, a charging current of about 40 amperes at 90 000 volts is required, equivalent to 6 200 k.v.a., and the voltage of the unloaded generators was found to increase from 1 300 to 1 800 volts when this line was thrown on.

An interesting point in the operation of these two power plants is that when water is not flowing over the spillways of the Great Falls plant, the only water that will reach Rocky Creek forebay

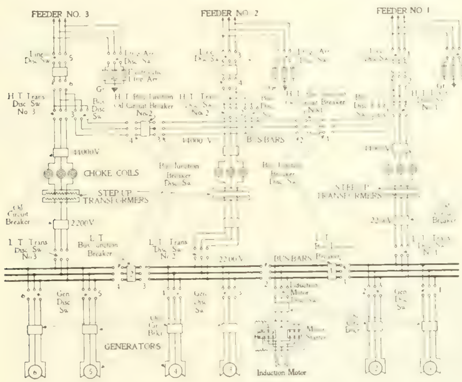


GENERAL PLAN NINETY-NINE ISLANDS STATION

Showing arrangement of hydraulic equipment, generators, switchboard, transformers and high-tension control apparatus.

must pass through the wheels at Great Falls. Hence, to utilize the full head of the water through both stations, the up-stream plant is so operated that the down-stream plant will always have sufficient water.

Four circuits leave the Great Falls 100 000 volt tie-in sub-station through automatic oil circuit breakers and are carried on two twin-circuit tower lines. Each tower carries one circuit of No. 00 stranded copper and one circuit of No. 00 equivalent aluminum stranded. Three 50 000 volt circuits leave Great Falls power house and are known as Great Falls Nos. 3, 4 and 5, going direct to Catawba switching station. Circuits 3 and 4 are on a twin



THEORETICAL WIRING DIAGRAM NINETY-NINE ISLANDS STATION

tower line and are of No. 000 stranded copper with hemp center. Circuit 5 is carried on a pole line and is of No. 000 equivalent aluminum stranded. These circuits pass through oil insulated, self-cooled choke coils at the Great Falls end and two of them are connected to aluminum cell lightning arresters.

NINETY-NINE ISLANDS GENERATING STATION

Work on a development on the Broad River at Ninety-Nine Islands was commenced early in 1909. This station was placed in operation in June, 1910, with a nominal capacity of 18 000 kw. The general arrangement of the apparatus is the same as in the station at Rocky Creek just described. There are six 3 000 kw, 60 cycle, three-phase, 2 200 volt, star-connected generators, operating

at 225 r.p.m., and nine 2 000 kw, 2 500/50 000 volt, single-phase, oil insulated, water cooled transformers, arranged in three banks, delta-connected on both high and low-tension sides. The arrangement of the exciter units is, however, quite different from that at Rocky Creek, for here the wheel casing is not in the bulkhead, but is set out on the floor lengthwise of the power house with the penstock coming through the bulkhead wall down to the wheel casing. The arrangement of the induction motor between the two exciter units is the same as at Rocky Creek. This motor is of 400 hp capacity at 2 200 volts, three-phase, and 580 r.p.m., while each of the exciters is of 250 kw capacity at 250 volts and 580 r.p.m., and is capable of supplying exciting current for all of the generators in the power house.

SUSPENSION TOWER CARRYING TWO 100 000 VOLT CIRCUITS

The Ninety-Nine Islands dam is of concrete and is of the spillway type, 1 600 feet long, 90 feet high, and holds back a pondage of over 900 acres. The operating head is 72 feet. Three lines leave Ninety-Nine Islands power house, each of which is carried on wooden poles. The lines are of No. 00 equivalent aluminum stranded cable and each is protected by an electrolytic lightning arrester.

The transformer house in this station adjoins the generator house at the end of the building instead of in the middle, as in the case of the two stations previously described. The exciter set is also at the end of the generator house in front of the raised platform on which are located the switchboard, control pedestals and instrument post.

TRANSMISSION LINES

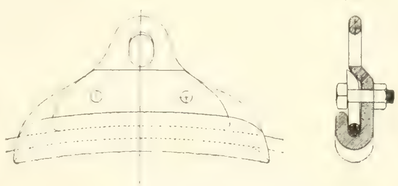
The 100 000 Volt Lines are carried on twin steel towers; one circuit is of No. 00 stranded copper and the other of No. 00 equivalent aluminum stranded. Each circuit is located in a vertical plane

on either side of the tower. The height of the lowest conductor from ground at the tower is 40 feet; of the middle conductor, 48 feet, and of the top conductor, 56 feet. The height of the top of the tower where the ground wire is located is 65 feet. The horizontal distance between conductors is 15 feet, 8 inches. Suspension towers are capable of withstanding the breaking of two conductors with normal wind strain of 15 pounds per square foot of projected conductor and 30 pounds per square foot of tower area on a 600 foot span. Strain towers are used where there is a change in direction of line of 30 degrees or less, and for every tenth tower. These towers are capable of withstanding the breaking of all wires in addition to the wind strain. Two strain towers are used for a change in direction of over 30 degrees. The average span between the 100 000 volt towers is 600 feet, while the maximum is 1 500 feet. Extra heavy towers are used on spans of over 1 000 feet, and for a change in direction through large angles.

SUSPENSION INSULATOR FOR 100 000 VOLTS

Anchors of an improvised type, having a foot made of 12-inch channel iron 30 inches long buried six feet in the ground, are used for suspension towers; for strain towers the anchor is buried eight feet in the ground. No concrete is used for tower foundations except when the direction of the line changes through a large angle or where the soil is very soft.

The suspension type of insulator is used on these lines, four in series on suspension towers, and five in series on strain towers. Cemented to the top of the insulator is a cap carrying an eye, while a hook is cemented into what normally would be the pin hole of the insulator. This gives a very simple and satisfactory method of fastening the insulators together. The top shell of the insulator has a diameter of 14 inches, while the inner shell has a diameter



DETAILS OF 100 000 VOLT FRASER SUSPENSION CLAMP

of seven inches. A very satisfactory type of suspension clamp was developed for use in connection with these insulators to hold the line wire.* The upper part of this clamp has a hole for the insulator hook on which it swings freely. The lower part has a groove curved to properly conform to the slope of the conductor. After the conductor is adjusted so that the insulator hangs vertically, the clamping piece is placed on the conductor and the two bolts are tightened. This gives a wedging action which holds the conductor as tightly as desired.

The suspension type of tower demands accurate calculation of sag with reference to the location of the towers, for they must be so placed that when the conductor is pulled to its proper sag it will hang as low as the clamp in the coldest weather regardless of the

TOWER AND POLE LINES
Right—100 000 volt tower line, carrying but one circuit (other circuit to be installed). Strain tower in foreground. *Center*—50 000 volt twin tower line. Strain tower in foreground. *Left*—50 000 volt pole line.

contour of the ground. Conductors when suspended cannot be tied down, as is often done on pin type insulators. The suspension tower normally takes only wind strain, so very light towers can be used, provided heavy towers are used at points where severe strains are to be met. All of the transmission lines of the Southern Power Company are equipped with overhead ground wire, grounded at each pole or tower. Three-eighth inch Siemens-Martin galvanized stranded steel wire is used; in fact, all metal parts, towers, pins, etc., exposed to weather are galvanized.

The 50 000 Volt Lines are carried on two different types of towers, the twin tower and the city tower, each carrying two cir-

*Developed by Mr. J. W. Fraser, assistant chief engineer of the Southern Power Company.

cuits. Only single circuits are carried on wooden pole lines. The twin tower is used across country with a strain tower every tenth support and at tangents. The twin tower line has an average span of 500 feet with a maximum of 1 260 feet, and carries two overhead ground wires. The city tower is used where the line is carried through thickly populated districts, with an average span of 350 feet and carries one overhead ground wire. Where pole lines are used, but one circuit is carried normally. Cedar and chestnut poles are used with yellow pine crossarms. The average span is 150 feet, while a maximum of 500 feet is obtained by the aid of bracing and guying.

CITY TOWERS
The towers shown in illustration at the left carry three circuits. Shown on tangent here.

The 50 000 volt insulator is of the three part pin type, thirteen inches high. The diameter of the top shell is twelve inches; that

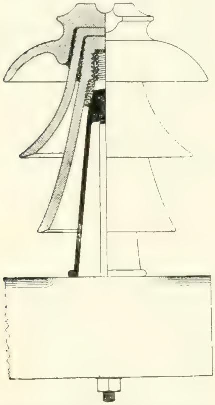
TABLE I—TRANSMISSION LINES IN OPERATION ON SOUTHERN POWER COMPANY'S SYSTEM

Lines	When Built	Voltage	Gauge	Miles Single	Miles Double	Miles Total
Wooden Pole	1904-5	11 000	2 & 00	40	12.5	65
Wooden Pole	1906-9	50 000	2 & 00	270		270
Wooden Pole	1906-9	50 000	00		65	130
Steel Tower	1906-9	50 000	00 & 000		55	110
Steel Tower	1909-10	100 000	00		240	480
Steel Tower	1910-	100 000	00	13		13
Steel Tower	1910-11	100 000				240
Total of All Transmission Lines.............						1 308

of the intermediate shell ten inches, and that of the bottom shell eight inches. A very strong construction* is used for holding this

*Devised by Mr. W. S. Lee, chief engineer of the Southern Power Company.

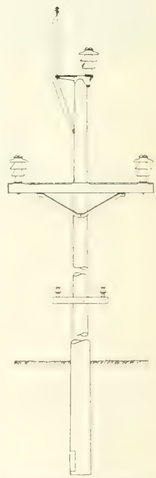
insulator to the cross-arm. The threaded pin hole of the insulator is filled with wet cement and a cast socket is threaded into it, having a tapped hole to take the threaded end of a pin. A cast thimble in the form of a frustrum of a cone with a hole in the top face supports the socket and the pin is passed through this casting and screwed into the socket. After the insulator, thimble and pin are placed in position on a cross-arm, a nut on the lower end of the pin pulls the socket against the flat surface of the thimble, brings the latter under compression and makes a very rigid fastening.



STANDARD 50 000 VOLT INSULATOR AND LEE PIN
Showing rigid construction.

SUB-STATIONS

By reference to the map of the transmission system it will be seen that Salisbury is the northernmost point of the loop composed of trunk lines. On one side of this sub-station are 50 000 volt circuits and on the other side 100 000 volt circuits. In order to feed power both ways over this loop as occasion may demand, the sub-station is tied into both lines by four 2 000 kw, oil insulated, water cooled, and two 2 000 kw, self-cooled transformers, arranged in two banks, delta-connected on the low-tension side and star-connected on the high-tension side, 50 800 volts high-tension, giving a line voltage of 88 000. Wall bushings are used on the 100 000 volt lines in this sub-station. An outdoor switching station is shortly to be erected just outside the sub-station. Seven electrically operated outdoor automatic oil circuit breakers will be installed. The bus-bars of the outdoor station will be carried on a special steel tower from which loops will be brought down to the circuit breakers. Points north of Salisbury can be supplied with power from either the 50 00 volt or 100 000 volt lines.



STANDARD WOODEN POLE

The tie-in sub-station at Spartanburg, which is worthy of special note, contains three 2 000 kw, single-phase, oil insulated, self-cooled transformers with a present ratio of 48 800 volts low-

TABLE II—SUB-STATIONS

	Stations	Ratio	No. of Transformers	Capacity of Transformers, kw.
		TIE-IN STATIONS		
	1	50 000/11 000	3	2 000
	1	100 000/50 000	7	4 000
	1	100 000/50 000	6	2 000
	1	100 000/50 000	2	2 000
	1	100 000/50 000	3	2 000
Totals	5		21	56 000
		11 000 VOLT SUB-STATIONS		
	5		3	100
	5		3	125
	4	11 000/2 200	3	150
	1	except in spec-	3	200
	1	cial cases.	3	250
	2		3	300
	1		3	500
Totals	19		57	9 825
		50 000 VOLT SUB-STATIONS		
	1		2	100
	1		3	125
	1		3	150
	7	2 200 volt	3	200
	1	distribution	3	250
	8	ordinarily	3	300
	5	used.	3	500
	1		3	750
	6		3	1 000
	1		6	1 000
	1		3	1 000
Totals	33		101	49 925
		100 000 VOLT SUB-STATIONS		
	1	2 200 volt	6	3 000
	1	distribution	3	3 000
	11	ordinarily used.	3	1 000
Totals	13		42	60 000
Grand Total	70		221	175 750

tension to 50 800 volts high-tension, giving a line voltage of 88 000 volts. The bus-bar structure used in this station, as in many of the other stations, is of one-half inch brass pipe mounted on suspension type insulators.

The Catawba tie-in sub-station contains three 2 000 kw, oil insulated, water cooled transformers tying in between the 50 000 volt lines from Great Falls and the 11 000 volt Catawba station bus-bars. An interesting feature in connection with this sub-station is that the 50 000 volt lines can be connected through above the roof of the station if desired, leaving the interior dead.

All metal structures, walls, floors and apparatus casings in all the stations are well grounded to prevent rise in voltage between portions of the building and between building and ground. If such precautions were not carefully taken such a condition might arise at times on a system of this size and voltage.

PART OF INTERIOR SALISBURY TIE-IN SUB-STATION

Showing one bank of tie-in transformers and high and low-tension station bus-bars.

The sub-stations connected to the system at the present time are given in Table II. The total of the high voltage transformer sub-stations is 70, with an aggregate capacity of 175 750 kw.

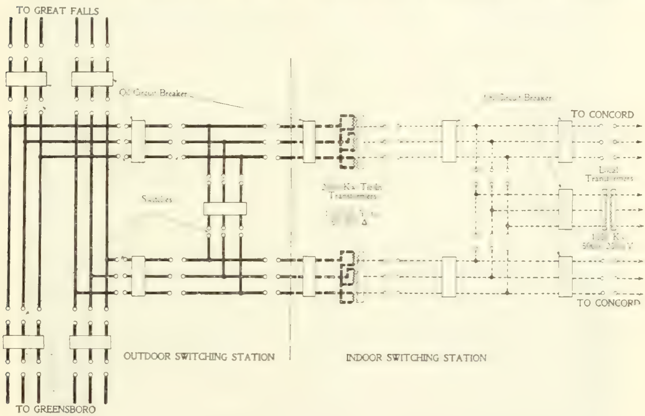
OPERATION OF THE SYSTEM

The headquarters of the operating department as well as the general offices of the company are in Charlotte, but the engineer on duty, directly in charge of operation, is located in the operating office at Highland Park sub-station, and is at all times in touch with each generating and sub-station of the system by means of a private telephone connection. From this point orders are issued to the station attendants directing the operation of the power houses, switching, use of lines, location of trouble, delivery of power, etc. In short, the dispatching of the load is taken care of here. This work demands intimate knowledge of the capacity of each station, line and switch and the switching possibilities available under any condition that may arise.

Telephone Service—The local battery type of telephone is used with No. 10 galvanized iron wire transposed frequently, depending upon the position of the line relative to the power circuits, which

are not transposed. Wherever possible the telephone line is carried on its own poles and in no case is it carried on the transmission towers, except for very short distances, for such practice would result in a noisy line and dangerous voltages on the wires. In case of failure of the private line the operators have recourse to commercial telephones and telegraph lines in the vicinity. In the event of any station being entirely cut off from communication with the operating office at Charlotte the operators have instructions to put their local load on any circuit carrying power.

Protection from Lightning—The entire region covered by the transmission system is subject to the most violent electric storms,



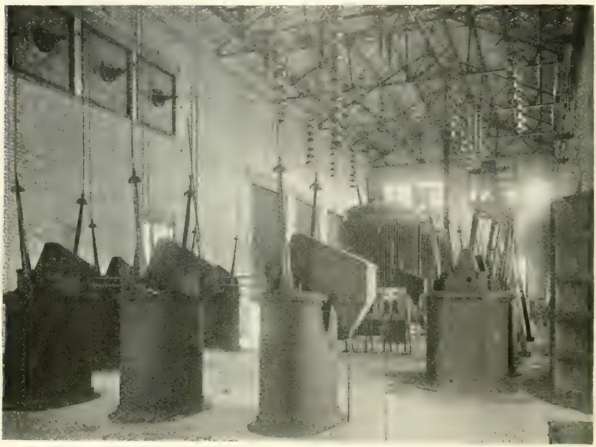
WIRING DIAGRAM, SALISBURY TIE-IN SUB-STATION AND OUTDOOR SWITCHING STATION

Tie-in transformers, 100 000 volts star to 50 000 volts delta; local transformers, 50 000/2 500 volts.

at least one storm occurring each month in the year, and during the summer months there is liable to be one or more storms every day. No trouble has been experienced with station apparatus from this source, but steel towers supporting pin insulators occasionally cause line troubles due to breakage of the insulators by lightning. For this reason jumpers are used across the pin insulators on some of the twin tower 50 000 volt lines, clamped at each end as a reinforcement at this point to help prevent the burning off of the lines in case of the formation of an arc. No type of lightning arrester has as yet been developed that will entirely prevent interruptions to service, but the presence of overhead ground wires

and grounding of structures has greatly improved conditions. There has been very little trouble on the 100 000 volt lines both on account of the higher voltage and because of the greater factor of safety obtainable with the type of insulator used. Lightning is the worst and about the only enemy that remains to continuity of service on long distance transmission systems to-day.

In general, the operation of lines carried on pin insulators mounted on steel towers is maintained in the face of far greater difficulties than if mounted on wooden poles, especially where the lines traverse country exposed to the violence of severe electric



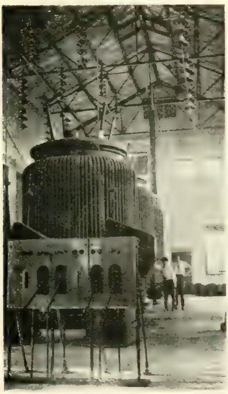
PART OF INTERIOR SPARTANBURG STATION
Showing hand operated automatic oil circuit breakers. Transformer bank in the back ground.

storms such as occur in the Piedmont section of the Carolinas. The growing scarcity of suitable wooden poles and the greater permanance of steel towers, and, further, the desirability of the latter where large amounts of power are to be transmitted, means that steel towers will be used more and more in the future.

The electrolytic or aluminum cell type of lightning arrester is used throughout this system with the greatest success. These arresters are placed out of doors. They are very effective in relieving the line of disturbances due to lightning and over-voltage due to surging and other causes, and the horn gaps can be set so close that

they will discharge on closing a switch many miles away, showing that they are extremely sensitive. With the gaps on these arresters set at two to three inches on 50 000 volts, two horns will discharge in case of a ground. The third horn will not discharge, thus showing that the line to which it is connected is causing the trouble and immediately indicating to the operator which line is grounded. This point is of no mean value to the station operator. These arresters have been found to give a heavy cushioning effect in times of trouble, thus materially assisting the power house apparatus.

Emergency Switching of Transmission Lines—At various points on the 50 000 volt lines are switching towers for the use of patrolmen in cases of emergency. One line can thus be cross-connected to anothed in order to disconnect a given section. The use of hand operated automatic outdoor oil circuit breakers both at 50 000 and 100 000 volts has become standard practice and, as no difficulty has been experienced in working this apparatus outdoors, it is expected as the system grows that the use of the outdoor type of circuit breaker, even of the mechanically interlocked double-throw types, will become more and more common. This company has been foremost in advocating the building of weather-proof high-voltage apparatus for outdoor service—especially transformers and oil circuit breakers— and they have found that there are points on a large system such as this where it is advantageous to install such apparatus. There are many problems to be met in the building of such apparatus, the most serious of which is that of bringing the high voltage leads through the iron covers. With the introduction of what it commonly called the "condenser type" of terminal, there appeared a type of bushing which easily lends itself to weatherproofing. Porcelain rain shields, gum filled, protect the insulation of the terminal from rain, but electrically they are not part of it. This type of terminal, which is in successful use under various conditions all over the country, is used on a large



TRANSFORMER BANK, SPARTANBURG TIE IN SUB-STATION
Showing oil circuit breaker operating board.

number of the 100 000 volt transformers, oil circuit breakers and 50 000 volt oil circuit breakers operating on these lines.

Housing of Employees—The operating department of the Southern Power Company maintains hotels at the larger generating stations for the housing of the employees and visitors. In beginning the work on a development, the hotel is usually the first building to go up, as care is always taken to see that the construction men have a suitable place to live. When the construction work is finished it becomes the home of the operators. These hotels are under the direct supervision of the superintendent of the division in which the power house is located, and are well managed. A number of rooms are always held in readiness for visits from the officials of the company and visitors in general. Those who have had occasion to visit the larger power houses easily recall the warm welcome, and the readiness and pleasure with which their many questions were answered and the details of operation explained.

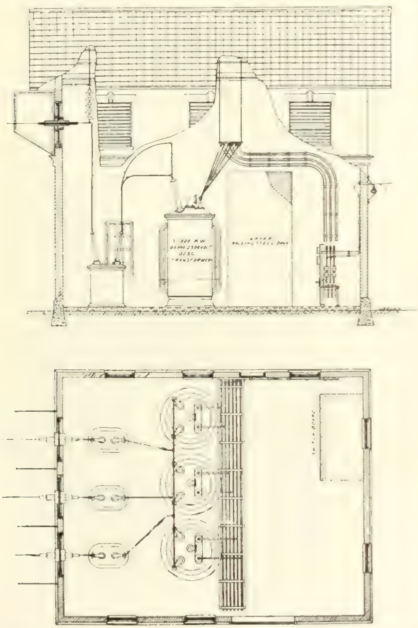
EXTERIOR SPARTANBURG TIE-IN STATION
Showing wall bushings, hoods, and steel doors at transformer entrance.

Load Characteristics—The load on this system is industrial in character, composed almost entirely of cotton mills with a few wood-working establishments. The load comes on about 6:30 A.M. and goes off at 12:00 noon; comes on again at 12:30 P.M. and goes off at 6:00 P.M. The equivalent 12 hour load of the entire system amounts to about 80 000 kilowatts at a power-factor of about 85 percent. The night load amounts to about 25 percent of the day load and is made up of lighting and power. This is an ideal load for this type of system, which is entirely water power at the present time.

The light night loads give the ponds time to fill up and the recuperative power is such that operation is carried on days at a time during periods of no rainfall with water flowing over the flash-boards in the morning and with a dry spillway at night.

SALE OF POWER

In the sale of power, service is divided into two principal classes—primary and secondary—according to the power requirements of the load. Secondary service is sub-divided into six-month, eight-month and ten-month classes. Primary power is delivered twelve months in the year, while secondary power is sold on a guarantee of delivery of service during 18, 24 or 30 months, as the case may be, in 36. During times of low water secondary power is cut off, and hence the customer using this service must have in partial readiness his own source of power, usually a steam engine. The operating department always endeavors to give secondary power users at least twenty-four hours' notice before cutting off their supply, so as to enable such customers to get their engines and belt connections to shafting ready.



ELEVATION AND PLAN OF STANDARD 3 000 KW, 100 000 VOLT SUB-STATION

The rates for the sale of primary and secondary power effective June 1st, 1908, are given in Table III.

Practically all power is now sold on a basis of 2 300 volts delivery, which is advantageous to both seller and consumer as it

gives the seller direct supervision over the operation and care of apparatus in the sub-station, while the consumer does not have to bother with the high-tension end.

FUTURE GROWTH

The work of development of the Southern Power Company is not over; in fact, it has just begun. Five years of work have achieved results far beyond the most sanguine expectations of those men associated in what was thought to be somewhat of an experi-

TABLE III—RATES ROR DIFFERENT CLASSES OF SERVICE

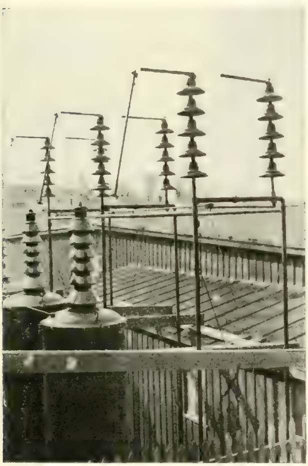
Service Requirements		50 000 Volt Service			2 300 Volts Delivered		
Hours	Horse-Power	Cents Per Kw-hr.	Dollars Per Kw-yr.	Dollars Per Hp-yr.	Cents Per Kw-hr.	Dollars Per Kw-yr.	Dollars Per Hp-yr.
PRIMARY DAY SERVICE							
11	250 and over	0.95	32.00	23.80	1.00	33.66	25.11
10	250 and over	1.04	32.00	23.80	1.00	33.66	25.11
PRIMARY NIGHT SERVICE (20 PER CENT OFF DAY RATE)							
11	250 and over	0.75	25.30	18.85	0.80	26.90	20.10
10	250 and over	0.83	25.30	18.85	0.88	26.90	20.10
SECONDARY DAY SERVICE—EIGHT MONTHS							
11	Under 500	0.66	22.10	16.50	0.72	24.20	18.05
10	Under 500	0.72	22.10	16.50	0.79	24.20	18.05
11	Over 500	0.55	18.45	13.75	0.60	20.20	15.05
10	Over 500	0.60	18.45	13.75	0.66	20.20	15.05
SECONDARY DAY SERVICE—SIX MONTHS							
11	Over 500	0.45	15.20	11.35	0.48	16.15	12.05
10	Over 500	0.50	15.20	11.35	0.53	16.15	12.05

ment, and one which had to be carried on in the face of continual opposition on the part of their only prospective customers at that time, the cotton mill people.

Conditions have changed until, in order to meet the remarkable increase in demand for power, other sources of energy must be acquired or developed. The Saluda River power station, recently acquired, has a capacity of 2 600 kw, and there has been built at Greenville, South Carolina, an 8 500 kw steam turbine station which will be ready to start in the very near future—the first steam plant of the Southern Power Company. There is also being built at

Greensboro, North Carolina, a duplicate steam station, and the machinery for the third has been purchased, but its location has not yet been decided upon. These units will be used as auxiliaries and will at times float on the line for power-factor control. Three miles north of Great Falls on the Catawba River is the Fishing Creek development, of 24 000 kw, the same capacity as the Great Falls station, which awaits the engineer to turn its energy into power.

Ten miles north of Camden, South Carolina, the projected Wateree development, on the Wateree River, which is a continuation of the Catawba River, is to be located. Approximately 100 000 kw is available here under a head of 85 feet, and there will be sufficient storage capacity behind this plant to deliver 80 000 primary horse-power for a period of thirty days without a drop of rain falling on the water shed of the Catawba River.

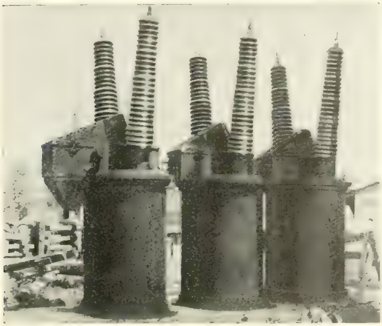


ELECTROLYTIC LIGHTNING ARRESTER
On 100,000 volt, three-phase grounded neutral line.

On January 1st, 1911, the Southern Power Company took over the plant of the Charlotte Consolidated Construction Company and affiliated companies which operate the street railways and gas system, and supply part of the electrical energy to the City of Charlotte. This plant will be tied into the transmission system of the Southern Power Company and the gas engine driven units which now supply part of the electric power to the city of Charlotte will be kept for auxiliaries for local service.

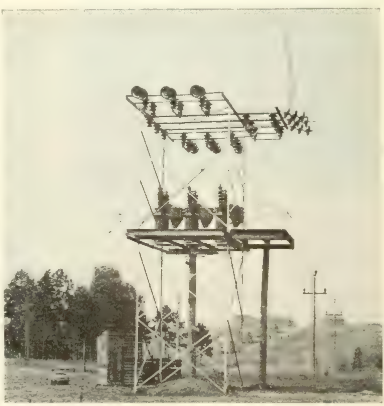
There is building at the present time at Great Falls, South Carolina, a 25 000 spindle cotton mill, which will take about 1 200 primary horse-power directly off the low-tension bus-bars of the station at this point. This will be the only power not transmitted at a higher voltage from this system. This mill will be one of the best equipped in the South and is preparing to manufacture the

finest grades of cotton goods in direct competition with New England mills. If the results warrant, more mills of the same character will be built here.



HAND-OPERATED AUTOMATIC OUTDOOR OIL CIRCUIT BREAKER, 100 000 VOLTS, THREE-PHASE
High Point, N. C.

Plans are being prepared for a fertilizer plant to be built a short distance north of the cotton mill to manufacture fertilizer by means of an electrochemical process for the fixation of the nitrogen of the air. This plant will take approximately 5 000 kw at the start. Many previous experiments along this line in this country have been failures, but by means of improved processes it is expected to manufacture so economically as to sell the product of this plant in competition with the natural nitrates imported from Chile. There is a demand for large quantities of fertilizer throughout the South, as the raising of cotton quickly exhausts the soil. Here, in what six years ago was a howling wilderness, will soon be enacted a scene of activity that was never even dreamed of, and this is but one locality where the transmission of energy has resulted in the development of unforseen enterprises. The increase in the



LINE SECTIONALIZING OUTDOOR TYPE, HAND-OPERATED AUTOMATIC OIL CIRCUIT BREAKERS, 44 000 VOLTS

Mooresville, N. C.

number of cotton mills in this region since 1904 has been very large.

That cotton mills are not to be considered the only principal market for power in this district in the future is a recognized fact, for at the present time there is a rapidly growing demand for better transportation facilities, especially between the smaller towns in this locality. The South is woefully weak in this respect, and the people have turned their eyes to electric traction to fulfill their wants. Preliminary surveys have been made throughout the Piedmont section for suitable interurban rights of way, and there is promise that in the near future better facilities will be provided between towns not only for passenger transportation, but also for a

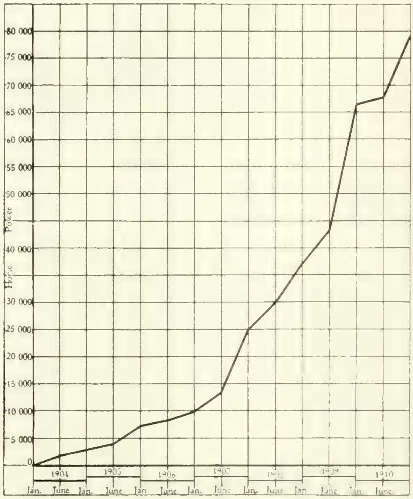
SOUTHERN POWER COMPANY'S STANDARD TYPE OF HOTEL
Great Falls, S. C.

large amount of freight and express business, and the motive power will be electricity. The successful operation of the very extensive interurban electric lines in the Eastern Central States, with their hundreds of miles of trackage, some of which are operating high speed electric passenger and freight trains and even sleepers, can be duplicated here. These lines can serve not only as feeders to the steam railroads, but also handle the interurban traffic to better advantage, under a closer headway and with far higher economy than a steam road.

CONCLUSION

The Southern Power Company is no mean determining factor in the development of the South; it is one of those forces that is

producing a new South—a South whose commercial influence will be felt more and more as time goes on. It is to men such as these, who by their foresight have realized the advantage not only to themselves, but to the community at large in financing enterprises such



CURVE SHOWING GROWTH OF THE SOUTHERN POWER COMPANY'S SYSTEM

as this one, in the face of an unpromising beginning; to men of the type of these who have designed, constructed and now operate so successfully this system of such large proportions, that the South is indebted for its present era of development.

ELECTRIC DRIVE FOR OIL WELLS

W. F. PATTON, Jr.

IT is generally understood that electricity is the power most suited for distribution over a wide area, because the losses caused by the transmission of power in this form are small as compared with the losses which are inherent to the transmission of other forms of power, as for instance, steam in pipes. In view of the fact that oil fields require power distributed over large areas, it seems almost incomprehensible that the electric motor is only now being generally adopted for operating oil wells. It is the more astonishing because the electric motor (although somewhat different in its operation from a steam engine) is as a whole at least as satisfactory for this kind of work as a steam engine, if it is designed to meet the requirements of this class of work. This has been proven beyond doubt by the experiments made with electric motors in the oil fields of the South Penn Oil Company in West Virginia, and it has been confirmed by the demonstrations made during the last year in the various oil fields of California with several improved types of motor.

Power is required in oil fields for drilling, pumping, cleaning the wells and moving the oil. The drill, used for boring the well, consists of a heavy cutting tool which is raised a few feet and dropped, thus forcing its way into the rock. It is supported by a steel cable and is given an oscillating movement, much the same as a weight on a rubber band, striking the ground at the time of maximum velocity, and being lifted by the elasticity of the cable as soon as the blow has been struck. As the length of the cable is continually changing as the boring progresses, the correct adjustment of speed to length of cable to secure the maximum rate of boring becomes quite a problem.

The presence of water in the hole greatly facilitates the process of drilling and the removal of the waste. To remove this water and waste a bailer is lowered into the hole, filled and raised to the top, the process being repeated until the well is sufficiently clean for the drilling to be continued. High speed operation of the bailer reel will, of course, save considerable time.

As the well is drilled, it is lined with a casing of iron pipe to prevent the sides from falling in. After the oil-bearing stratum is reached, a second line of smaller pipe, terminating in the pump barrel, is lowered inside the casing to the bottom of the well. In-

side this tubing is lowered a series of rods with the pump sucker and ball valve at the lower end. The upper end of the rods is attached to the walking beam, and the well is ready for operation. Power for pumping the oil from wells has been supplied, in most cases, by small steam or gas engines.

Electric motors were first installed for the operation of oil wells in 1903, when the South Penn Oil Company, of West Virginia, purchased 250 motors for pumping oil wells. The power was generated in a central station, near Folsom, West Virginia, which was operated by natural gas, but had at the same time a steam plant for reserve. The motors pumped the wells very satisfactorily from the beginning and also gave good results in pulling the tubing for cleaning, etc. The South Penn Oil Company, therefore, installed 150 additional motors in 1905 and 50 more in 1907.

The motors are mounted on a cast iron base and geared to a countershaft mounted on the same base. The countershaft carries a pulley for the large bull wheel belt. The motor, with its countershaft, is arranged in place of the engine. The controller for the motor is in the motor house and is operated by a handwheel in the derrick, which takes the place of the throttle wheel at the steam engine. The reversing lever is not required.

Motors for pumping must be of the variable speed type, as the speed of pumping must be varied from time to time, the number of strokes per minute ranging from 16 to 30, depending on the condition of the well. Maximum pumping speed is always desired, but if the speed is too high an excessive amount of sand will be pumped. The average speed of these pumping motors is about 560 r.p.m. when pumping. They can be speeded up to about 700 r.p.m. for pulling out the tubing when the pump becomes clogged with sand or whenever otherwise desired.

The only drawback to the electric drive in the fields of this company was due to the fact that the wells now and then required redrilling and the motors above mentioned were not suitable for this work. It was, therefore, necessary to install a boiler and steam engine every time the redrilling was to be done, and, on account of the poor road conditions in the territory, the hauling of the boiler and steam engine is rather expensive. This led Mr. Clarke, chief engineer of the South Penn Oil Company, who is considered as a pioneer in the introduction of electric motors into oil well work, to make numerous experiments with electric motors with the intention of designing one which would also be good for drill-

ing work. He had built in 1906 an experimental motor which, after some trial, gave satisfactory results for the drilling work, and was so similar in its operation to the steam engines, that the drillers quickly recognized its advantages.

Encouraged by this experience, Mr. Clarke ordered two new motors of the same general type which were put into service in 1908 and have given satisfactory results ever since. These motors have two stators mounted in a single frame, one of which is arranged to be rotated through a small arc by a worm gear. The core of the rotor is in two parts, each keyed solidly to the shaft, with the bars of a squirrel cage winding extending through both cores. By rotating the one stator relative to the other, the speed may be reduced to any desired value, with high efficiency at any speed. In addition, each stator is wound for two speeds by means of a

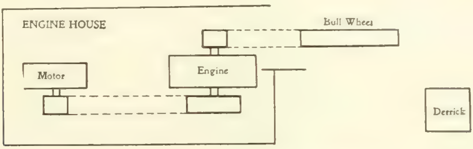


FIG. 1.—PLAN OF PUMPING EQUIPMENT
Motor in extension of engine house. Engine fly-wheel replaced by 60-inch pulley.

pole-changing device, so that double speeds may be obtained for bailing or wherever high speeds are necessary.

These motors were designed for comparatively high speeds and required gear reductions. The gears were, as in the case of the pumping motors, the only cause for some slight trouble, since work in the oil fields is very severe on machinery and this frequently results in the breakage of gears. Mr. Clarke, therefore, decided in the future, to use motors for drilling having the same speeds as the steam engines, and which could be belted directly to the bull wheel. Ten such motors were installed in 1909 and have been in operation since that time. According to the remarks of oil well drillers, these motors represent the ideal for oil well drilling work. They are generally used for deeper drilling and have drilled an average of twenty holes each per year since they were installed. Some of the motors were also used for new drilling with very good success, and Mr. Clarke has drilled three complete wells of 2 100, 2 600 and 3 200 feet in depth. The drilling speed obtained is higher than can be obtained with steam engines.

Since these drilling motors are somewhat more expensive than the motors used for pumping and pulling the wells, it does not appear economical to follow the steam practice which consists of using the same engine for drilling and pumping. It is advisable, in case of the electric drive, to do the drilling with one of the larger drilling motors and afterwards install a smaller motor for pumping and the ordinary cleaning. When it is necessary to drill deeper, one of the drilling motors can be easily moved to the well.

FIG. 2—ENGINE HOUSE AND DERRICK OF MOTOR DRIVEN OIL WELL

In 1909, the question of electric drive for oil wells was taken up in Southern California. Since alternating current is used in California at a frequency of 60 cycles (while the current used by the South Penn Oil Company had a frequency of 25 cycles), it was not possible to use the same practice and the same type of motor. The motors for 60 cycle operation cannot very well be designed for as low speeds as the motors for 25 cycles, and it is, therefore, not possible to connect the 60 cycle motor directly to the bull wheel by a belt.

In the first experiments, the piston rod of the steam engine was disconnected and the flywheel on the engine shaft was replaced by a large pulley, which, in turn, was driven by an electric motor. This arrangement had the advantage that if anything should happen to the electric motor on account of the fact that the oil men were not yet familiar with the electric drive, it was an easy matter to remove the belt from the motor and put the steam engine to work. This arrangement has proven so satisfactory that up to the present time all motors installed in the California fields are oper-

ated in this way. After a short time it will, of course, be possible to dispense with the steam engine entirely and put a simple countershaft with two bearings and two pulleys in its place.

Another possible alternative of such an arrangement would be a back geared electric motor which could be placed on the present engine block. While this arrangement undoubtedly has the advantage of being more condensed, it is not to be recommended for heavy work, since gears are always liable to break under service conditions as severe as those in the oil fields. Moreover, the gears are not as flexible as a second belt, and since with careless handling

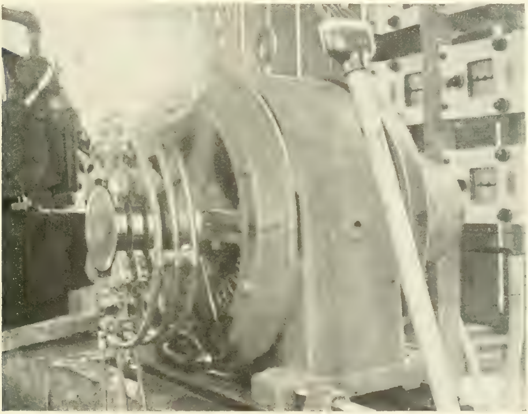


FIG. 3—WOUND SECONDARY INDUCTION MOTOR, USED IN PUMPING OIL WELL

The motor primary can be changed from star to delta connection by means of a double throw switch. Rating, star connection, 10 hp continuous duty; delta connection, 30 hp intermittent duty.

the electric motor can be very suddenly started and stopped, the flexibility introduced by a second belt is very desirable because it is less liable to cause breaks in the piping and the rods when they are pulled. If gears are used at all, the motor speed should not be too high. With the low speed used by the South Penn Oil Company, for instance, the breakage of the gears on the pumping motors is so small that it is not a serious item in the running expenses.

With the double belted arrangement it is impossible to install the electric motor without slight changes in the arrangement. In place of the steam engine, a countershaft with two bearings and

pulleys, as mentioned above, is to be installed, while the motor can be put between the reel for the bailer cable and this countershaft. This necessitates the building of a small additional house, but the expense is fully counterbalanced by the advantage of the double belted arrangement.

The first double belted motor was installed in the Sherman oil fields near Los Angeles early in 1910 and has been operated for pumping and cleaning without interruption since that time. On account of the necessity of cleaning the wells, it was necessary to have a reversible motor, with the speed adjustable for pumping, which would give a slower speed on the upstroke than on the down stroke, and which could at times develop a very high torque for pulling and cleaning. It is customary to pull the pump rods and pump first and then the tubing. At times, however, it is impossible to pull the pump out of the tubing and it becomes necessary

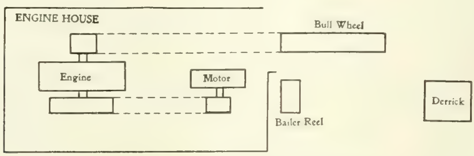


FIG. 4—PLAN OF PUMPING EQUIPMENT
Motor in engine house, between engine and bailer reel. Engine fly-wheel replaced by 60-inch pulley.

to pull up the tubing full of oil, and the pump rods at the same time, requiring a very high torque.

To meet these conditions, a wound secondary motor was installed, the speed being varied by inserting resistance. The primary is arranged for either delta or star connection, so that by simply throwing over a switch it can be changed from a ten horse-power constant service to a 30 horse-power intermittent service rating. The well at which it was installed is 2 000 feet deep with 2.5 inch tubing, and about 40 barrels of 15.5 degree gravity oil are pumped per day on 24 hour service.

Extended tests were made, which developed the following:—

I—The ten horse-power arrangement of the motor gave ample power for pumping service; in fact, on this particular well, it was found that only six horse-power was required. The variable speed feature also proved desirable, as it enabled the operator to adjust the pump to the speed necessary to give the best results.

II—When, by throwing the change-over switch, the capacity

of the motor was increased to 30 horse-power for intermittent service of half-hour periods, it proved perfectly satisfactory for pulling rods and tubing and other work incidental to cleaning the well. In order to accomplish this work rapidly, a change of pulleys was made on the motor which would give double the belt speed used in pumping. This was a simple operation, as the six-inch belt connecting the motor to the countershaft was easily handled.

In September, 1910, other motors were installed in the Coalinga oil fields. One motor was installed on the Good Luck Lease and performed satisfactorily from the beginning. It was demonstrated

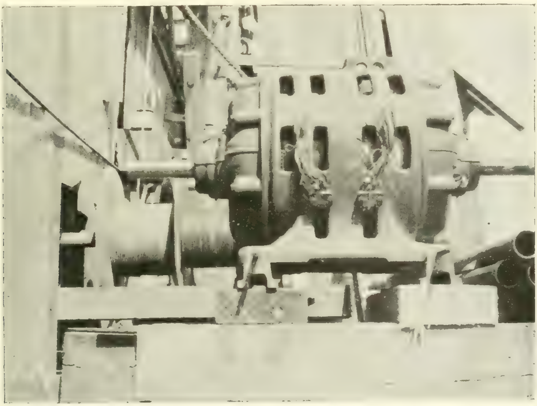


FIG. 5—DOUBLE PRIMARY DRILLING MOTOR

One primary can be rotated relative to the other by means of a worm gear, so that any speed below synchronous can be obtained for the squirrel cage rotor, at good efficiency. By means of a pole changing device the synchronous speed can be doubled for bailing, etc.

beyond doubt that the well, which has a two-inch pipe, is about 1 500 feet deep and pumps about 30 barrels of oil and 60 barrels of water per day, can be operated for $1.50 per day, while it would cost $3.00 per day with steam operation. The complete pulling of this well was done at the rate of 90 cents for current consumed. On account of this excellent showing, the Good Luck Company ordered motors to operate all of their wells, which have given equally good results.

After the first Good Luck motor was installed, experiments were started on a well of the Kern Trading & Oil Company, which is the largest company in the Coalinga fields. For the first motor,

the heaviest well was selected, and, although the motor installed was not designed for a well of this capacity, its performance was quite satisfactory from the beginning. It was proven that, although the motor was too small for this work, a length of 1 900 feet of three-inch piping could be pulled in less time than had been taken with steam, and it can be predicted with certainty that with the proper motor the time required for pulling can be reduced to two-thirds of the time required by the steam engine.

In this case, as well as with the first motor of the Good Luck Company, the motor was not installed near the reel of the bailer cable, but in an extension of the engine house as indicated by Fig. 1.

FIG. 6—MOTOR HOUSE AND DERRICK, EQUIPPED FOR DRILLING WITH ELECTRIC POWER

A general view of this outfit, showing the extension of the engine house, is given in Fig. 2. Fig. 3 shows the motor installed in the engine house extension. Several motors installed later were arranged, as described above, by placing the motor between the bailer reel and the present engine, as indicated in Fig. 4.

Experiments were started at the same time with a drilling motor on the premises of the Kern Trading Company, arranged in the same manner as shown in Fig. 4. Fig. 5 shows this motor while being installed, before the motor house was built, and Fig. 6 shows the motor house. The power circuit and the transformers on the poles, while being installed, are shown in Fig. 7. The results obtained with the drilling motor were satisfactory, but the

motor could not be kept in service very long on account of the completion of the well. Further demonstrations will, however, be made with this motor in the near future.

The controllers of the first motors installed in this territory were very similar to a common street car controller, with one handle for reversing and changing the speed. These were installed in the derrick close to the well in order to be convenient for the operator. In later installations the controller was placed in the motor house and operated by means of a steel cable and a hand wheel, making the control very similar to that of the steam engine. Over-

FIG. 7—INSTALLING TRANSFORMERS FOR DRILLING AND PUMPING MOTORS

load and no-voltage release devices are usually provided as a protection to the motor.

The controller contacts are immersed in oil so that all danger of gas explosions from sparking at the contacts is eliminated. As additional protection against explosions the brush rigging of the motor is completely enclosed in a fine wire gauze screen. The freedom from the danger of gas explosions forms one of the valuable features of the electric drive, as considerable trouble has been experienced from this source in the past. One recent experience with flowing gas, while using steam engine drive, resulted in the complete destruction of several rigs by fire, with a complete loss of output from the wells for several months.

THE NEW METHOD OF INDUSTRIAL TRAINING

"Of 1666 men recently applying for work at the gate of a plant employing about 15 different trades, only 134, or eight out of each hundred men even pretended to be anything more than unskilled laborers. However, upon such men manufacturers depend for a large part of their output."

The foregoing statement is taken from the summation of a session devoted to the subject of "Apprenticeship and Corporation Schools" at the recent meeting in Boston of the National Society for the Promotion of Industrial Education. The several papers and the discussion give an admirable view of the educational problem which the new industrial conditions have created.

The following papers and discussions are greatly condensed from Bulletin No. 13 of the proceedings of the Society which contains the papers and discussion of Friday morning, November 18, 1910.

APPRENTICESHIP AND CORPORATION SCHOOLS

Magnus W. Alexander, General Electric Company, West Lynn, Mass.—Chronologically, apprenticeship was the first step in trade training. The introduction of labor-saving machinery and of specialization of processes in the middle of the last century, inaugurating a wonderful revolution in the industrial life of America, tended to eliminate this system. Under the new industrial conditions there seemed to be no great need for the all-round skill of the trained apprentice. Manufacturers relinquished their previous responsibility for the training of men more readily because the public school system began to incorporate manual training in its curriculum. Industry expected to receive at once better industrial recruits, where it should have looked only for beginners with a better understanding of the industrial life.

The fallacy of this assumption soon showed itself; the industrial leaders could not command a sufficient supply of all-round skill to guide the large industrial army of machine operatives and instruct them in the various processes; to design and build the complicated machinery which specialization of manufacture had necessitated, and keep it in good order and repair; and to develop the leadership on which the expanding industries had to depend for their very existence. Manufacturers of a decade or so ago interpreted the principles of apprenticeship in terms of the new industrial and social conditions, and inaugurated new systems responsive to the new demands.

The modern apprenticeship idea, grown out of the changed industrial and social conditions of today must be considered as to its place in the scheme of industrial education. Its life's blood is pulsating anew in the veins of industrial life, and its flow should be quickened and extended into all arteries of industrial activity for the reason that a well-regulated, modern apprenticeship system will give satisfactory results to the industries promptly, and immediate opportunities for trade training to boys, and furthermore, will serve as a practical object lesson to those who are faithfully working on the establishment of effective trade schools.

HOW THE WESTINGHOUSE COMPANY TRAINS ITS APPRENTICES

Tracy Lyon, Westinghouse Electric & Manufacturing Company, Pittsburg, Pa. We are giving our trades apprentices a certain amount of class room instruction during working hours and also support in part a night school, of which the majority of the instructors are men in our employ—for the most part from the Engineering Department.

The apprentices are in the class room four hours a week during the entire year and are taught mechanical drawing and arithmetic in the shape of shop problems.

The main thing in view is to awaken the boy's intelligence and start him to thinking in an accurate way about what he is doing. He may have a common school education and may perform his task of operating a machine tool fairly well, yet for the rest of his life may fail to thoroughly understand the drawing he is working to, and quite fail to apply to advantage whatever knowledge of mathematics he may have. To be able to read a drawing quickly and intelligently is, in a way, as much an accomplishment to be acquired as to be able to read any other form of expression, and the man who can solve quickly and accurately the many little problems in time and dimensions which come to a workman, has certainly increased greatly his value to himself and his employer.

This is certainly a fruitful field—if some of these boys were left to themselves, if some awakening process were not applied to them at this critical time in their lives, it may be fair to assume that they might slumber to the end.

We hope to make all-round mechanics of the majority of the boys. Some, perhaps, will prove capable of attaining skill in the operation of but one tool, and in this we will help them to their highest efficiency. Of others we will be able to make fore-

men—and of course there is no limit to the promotion which these may achieve. The crying need of the industrial world to-day is for men who can think as well as work, and this pertains all along the line from the bottom to the top. There is more, too, to be taught to these boys than drawing and arithmetic—the spirit of service and willingness, of order and the application of system and common sense to their daily problems. It may also be possible to make them realize, and few workmen do, that there are many employers of labor who are willing and anxious to pay adequately for a higher quality of workmanship and greater efficiency.

We have in the works an apprentice department under competent instructors—it is quite well recognized to-day that the old practice of turning boys loose in a shop, subject to the tender mercies of the foremen, is an injustice both to the boys and their employers—and we intended at first to keep the boys in this department for a year and a half or two years before sending them into the shop for the remainder of the four years course. Recently, however, we have adopted the plan of first grounding the machinist apprentices thoroughly in the construction and use of a standard machine tool—a lathe, for instance—then sending them into the shop to gain a certain amount of experience in the operation of this tool, and after this is acquired, bringing them back and repeating the process with another tool. During their entire apprenticeship the boys are under the general supervision of the foreman of the apprentice department.

To those of the boys who wish to broaden their studies the night school of which I have already spoken is open, and the fact that at least twenty-five per cent of the present trades apprentice classes have taken advantage of this opportunity is an encouraging one. It is in no sense a trade school, although its equipment includes electrical, steam, physical and chemical laboratories, a pattern shop, small foundry and machine shop, but is intended to provide an opportunity for the study of fundamental engineering and its application to shop practice. There is also a special course for shop men, intended for those who have had long experience in the trades and preparatory department, in which spelling, reading, writing and grammar are taught, for young boys and foreigners. We have a large number of foreign-born employees and recently discovered that over fifty different nationalities were represented among them.

We also have a two-year apprenticeship course for graduates of technical colleges, this period being spent in various departments of the works and offices. There are several hundred men enrolled in this course, which presents many difficult questions in the determination of its scope and of the direction in which the work of each man should be guided.

The social and athletic side of student life is encouraged and the rooms and gymnasium of The Westinghouse Club, which is open to all of the employees of the Westinghouse Companies, who largely support it, are very well equipped. Instruction is provided through courses of lectures and organized technical sections, as well as by means of less serious talks, excursions, etc.

All of these provisions, involving a large expense for what might be called industrial education, are of little avail unless they are administered in an effective way and with a thoroughly sympathetic spirit, and I have been much impressed by the unselfish devotion and interest shown by the men to whom this work has been intrusted or who have volunteered in its behalf.

EDUCATING APPRENTICES ON THE SANTA FE

F. W. Thomas, Supervisor of Apprentices, Atchison, Topeka & Santa Fe Railway System, Topeka, Kan.—The present apprentice system had its birth when the road was in crying need of skilled mechanics. There was work in abundance, but the laborers were few. The management said, "If we can't hire them, we will make them."

In each shop of this company, all the way from the great lakes to the Pacific coast and down to the Gulf of Mexico, a building or room has been set aside as the apprentice school room, and in these schools the boy is required to spend two hours a day, two days a week. He is taught free-hand and mechanical drawing, practical shop arithmetic, the simpler elements of mechanics and certain geography and history relating entirely to the road.

There is no bunching of boys together, rushing the duller and slower boys over the course, or holding back the quick, energetic boys, but each progresses just as rapidly as his ability or capacity will permit. No text books are used, but standard lesson sheets, written and printed in the office of the superin-

visor of apprentices, are sent to each of the various schools. Each lesson refers to some part of a locomotive, car, shop tool, or some feature common to railroad work.

Apprentice school instructors are selected with great care. As a rule, young men are preferred to older ones, as there is a greater tendency for younger instructors to "mix" with the boys, to join with them in their sports and really become a part of their lives. The function of school instructor is to teach the boy to use his brains along with his hands and eyes, to reason out, and to understand the work in the shop as he progresses.

We have been endeavoring to impress upon our young men the importance of cleaning up before leaving their work at the shop; to cease loafing on the street or at disreputable places; if they go to shows or places of amusement, to select the best kind; to be polite and courteous. The effect has been noted at a number of places—in fact, the personal appearance and social conditions at some of these places have been revolutionized. Such teaching has also made them more orderly in their work, keeping their shop tools, hand tools and jigs clean and in the right place. Wherever we have an apprentice school, it has even now a decidedly elevating moral effect on the shop body. The school is no longer considered an experiment; it is considered a necessity.

The Santa Fe is spending from $35 000 to $40 000 a year training boys for its future needs, yet with the help of their school and shop instructor, these boys are accomplishing enough more work to more than pay for the cost of instructing them. Our primary object is to make mechanics for our shops. We can hire all the mechanical engineers, draughtsmen and college men we want, but our pressing need is first-class mechanics.

Any corporation that requires the apprentices to return regularly at night to attend school is courting failure. The boys out of whom we can make our best men have an abundance of red blood in their veins and must have some hours for recreation and play.

We teach our boys that all the brains in the country are not in the medical or legal professions, or even within the halls of Congress. We teach them that fully as many brains are engaged in mechanical, electrical and mining engineering as in the other professions.

A COÖPERATIVE APPRENTICESHIP SCHOOL

Samuel F. Hubbard, Superintendent, North End Union, Boston—The North End Union School of Printing, of which I am to speak, differs from the corporation school in that it aims to serve as many different employers as possible, and bring them together into an organic administrative whole for trade school purposes. It was started as an evening school for boys already at work in the trade of printing. Six years ago the plan was entirely changed, a day school was opened, which aims to ground a boy in the fundamentals of his trade.

It is a common remark that the place to learn a trade is in the trade itself. There is a lot of truth in this statement, provided the trade undertakes the training of an apprentice in a thorough, systematic manner; but even then a trade school can make a distinct contribution to the training. The conditions of the modern shop, under which productive methods are keyed up to concert pitch, are almost prohibitive of opportunity to train apprentices along with the daily routine of work. If a shop has apprentices enough, it can maintain its own training school. The wisest and most economical way for several shops having but few apprentices is "to pool their issues" and open a trade school for the trade as a whole.

Trade schools, to be effective, must be dominated by those whom they serve, namely, the employer and employee. If supported in part by public funds, the town or state supplying the public funds should have a representative on the board of management. The schoolmaster will be expected to present the boy at the door of the trade school, not only prepared to take up the work of trade training, but prepared for good citizenship as well. This preliminary training should enable a boy to think—think straight; to think in words, written and spoken; to think in numbers; to think in drawings; and should give the training which enables the hand to give expression to thought. All these are essential to the foundation of trade training.

The employer will spend his money freely for the most approved machinery. When it comes, however, to training his own employees to meet the increasing demands for greater skill, or to supply the waste caused by depreciation, it is entirely a different proposition. The fact is, the employer has got to be educated and made to see his responsibility in the training of apprentices.

A HALF-TIME SYSTEM OF APPRENTICE INSTRUCTION

George G. Cotton, Solvay Process Company, Syracuse, N. Y.—Owing to the peculiar nature of the work of the Solvay Process Company, consisting of chemical processes requiring continuous operation throughout the year, it is necessary to have operatives and mechanics who have been trained in the special work of the Company.

It was established from an examination of our shop records that the boys and men who came into the employ of the Company comparatively green and learned their trade as mechanics, and are now our reliable men in their several lines, have spent on the average about six years acquiring their branch of the trade. These conditions require the trained employee to give time and attention to the instruction of new men and boys at the cost of interference with their own work and with considerable trouble and expense to the company. The Solvay Mechanics School was therefore established by the Solvay Process Company for the purpose of giving preliminary training in order to obviate the difficulties mentioned. The boys work one week in the shop and then one week in the school, being paid for their time both in the shop and in the school. Time in the shop follows the regular shop schedule; the school hours are from 8 A. M. to 3 P. M. with a noon recess.

The school being located in the laboratory building inside the works and near the shops, gives the committee ample facilities to keep in close touch with its workings. The school room is furnished with plain flat-top tables with ordinary wooden-seated chairs, and has blackboards on the walls. The boys use their shop tools, such as rules, dividers and calipers, and for the purpose of demonstration, we have apparatus, machinery, tools and parts of same, packing, lubricants, oils, acids, etc. Free-hand drawing, mathematics, strength and formation of materials, mechanics, equipment, preparation of reports and current topics both written and oral are taught.

DISCUSSION

Walter R. Russell, Director, Franklin Union, Boston, Mass.—The direct public benefit from corporation schools is far-reaching and is not confined to the improvement of men in skill alone. Public or independent continuation or improvement schools, organized with the particular aim of supplementing the

daily work of men in the shop, are doing for many corporations at once the same work that is being handled by the larger companies for themselves.

One feature of the movement which has thus far received only scant emphasis is the small apprentice school. Several of the most successful schools on record have been established in small shops.

The corporation school, whether in dry goods or railroad shops, is at its best when kept close to real conditions, and when its teachers come from the trade or industry rather than from school.

Sydney W. Ashe, General Electric Co., Harrison, N. J.—I shall first outline the educational work which we are now carrying on at Harrison, New Jersey, for the General Electric Lamp Works, after which I shall give a few of my observations pertaining to college graduates.

The educational work consists of, first, the training of a corps of college men; second, the training of men to sell lamps; third, the training of the salesmen already in the field; fourth, the training of a corps of experienced men, who remain attached to the home office as specialists on various subjects; and, fifth, the training of the factory and office forces.

The greatest advantage of all of this educational work is that all passes through one common center of distribution, and owing to the proximity of the factory to the sales department, the element of coöperation will be utilized to its highest extent. This work has been carried on for about a year, but has recently been reorganized and expanded.

The necessity for a corporation school for college graduates arises from the fact that for four years the average student has been accustomed to absorbing knowledge; to having his program definitely arranged for him, having some one behind him to push him; or in other words, the whole atmosphere has been one of absorption. When the young man enters the corporation the process is reversed—it is one of giving out, instead of taking in. His first year, therefore, becomes one of readjustment.

In the past it has been stated that universities should give special courses in electric light and other special subjects. It is felt, however, that the purpose of educational institutions is to concentrate on fundamental principles, and it is time enough when the man enters commercial work to learn the individual

specialties. In other words, there is nothing the matter with our present college courses except that it would be to their advantage to develop somewhat more the personal element of the individuals.

G. M. Basford, Assistant to the President, American Locomotive Company, New York, City—The boy is in the shop and we must move the school to him for we cannot move him to the school. We cannot wait for the educators to adapt themselves to our problem, but must take it in hand ourselves—hence the corporation school. It meets the need because the boys who come to us are those who must work every possible working hour in order to make a living. They cannot afford to go to school. Even if they could learn trades in trade schools they cannot afford to do so. It is most direct and definite educational work. Because the boy is making his place among men while acquiring his education and is educated in his work while at work, this type of school surpasses all others in directness, definiteness and in conservation and concentration of the attention of the mind of the boy. To these advantages another of great importance is added. The boy does not finish his school work and then find it necessary to establish himself in a working position. He is already in such a position.

It is perfectly safe to accept the proposition that apprenticeship is to be a permanent factor as an American institution. By this is meant the new apprenticeship, involving real shop training by men who have direct responsibility for teaching trades, and have time for this work because they have nothing else to do. Trade schools, unless followed by apprenticeship, do not, and I believe can not, meet industrial need of the times.

The movement was carried completely across the continent in two jumps by the New York Central and the Atchison, Topeka & Santa Fe Railways. Manufacturers are not likely to be slow in adopting methods which have so abundantly proven their merit as these have done. Let us also remember that many boys with the best possibilities, for one good reason or another are obliged to leave school at an early age, and that the world to-day places great responsibilities upon men who have risen from the ranks of such boys.

SOME STEAM TURBINE CONSIDERATIONS (Concl.)

EDWIN D. DREYFUS

OPERATING CONDITIONS

A DIFFERENCE of opinion sometimes exists among engineers as to the boiler pressure, superheat and vacuum most suitable for turbine operation. Quite naturally, the wider the limits of the working range of the steam, the lower the water rate of the turbine or engine becomes, due to the greater amount of energy made available in one pound of steam, as illustrated by the temperature-entropy diagram for steam, shown in Fig. 12. Obviously in selecting power plant working conditions, it is unwise to strive for the highest efficiencies in the prime mover at a sacrifice in operation of the boiler and condensing apparatus. It is practicable at the present time to carry pressures as high as 250 lbs., gauge, and superheats of 150 degrees and above, as well as to maintain a vacuum as high as 29 inches for the greater part of the time when the injection water temperature is 65 degrees and below. But the question logically arises, does it pay to resort to these extreme ranges to show the highest possible results in the prime mover. A brief review of the factors to be reckoned with will forcibly indicate the use of moderate conditions. For increased pressures, say above 150 lbs., the amount of energy made available is relatively much smaller than at the lower ranges. Furthermore, high boiler pressures require more expensive boilers and piping, so that 175 lbs. pressure is found to be more suitable for large units, while for smaller machines the pressure might with propriety be made lower. Superheats of 100 and 150 degrees are entirely feasible with superheater tubes placed in the boiler setting, and up to this point the efficiency is not materially affected by having the superheating surface placed in the second pass. It is not advisable to exceed the higher figure and, in fact, many engineers prefer to keep within 100 degrees, and are supported by such convincing facts as are shown in Fig. 13. All assumptions in calculating this diagram were made to favor high superheat so that, considering the deterioration in the system accompanying the higher temperatures, 100 degrees F. may safely be taken as the upper limit. Higher superheats require the best obtainable grade of pipe fittings, and the maintenance cost of the superheater and piping are generally greater.

The turbine is inherently efficient in the low pressure ranges, but the additional cost in power, investment and maintenance, to provide for the highest vacuum obtainable is too frequently overlooked . Steam temperatures at the low absolute pressures fall off very rapidly, as the curve in Fig. 14 shows. This limits the temperature rise possible in the injection water and consequently a

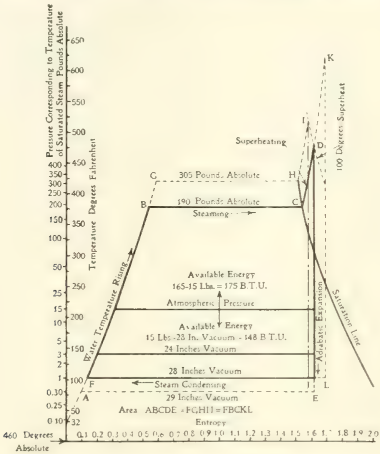


FIG. 12—TEMPERATURE ENTROPY DIAGRAM FOR STEAM, EXHIBITING THE INFLUENCE OF HIGH VACUA

This diagram can be appreciated without a thorough understanding of thermodynamics. It need only be borne in mind that heat is the product of two factors—absolute temperature and the rate of heat transfer (entropy). Therefore, these factors may be plotted as co-ordinates and areas obtained representing the equivalent energy in B. t. u. Steam engine performances are frequently referred to the Rankine cycle as a basis of comparison, such a reference being generally known as the efficiency ratio or thermodynamic effieciency of the engine. The four operations of the cycle, for simplicity assumed to take place in the engine cylinder, may be appreciated at once: (a) heat is imparted to water; (b) heat of vaporization is supplied; (c) adiabatic expansion occurrs (without taking or giving up heat, being consequently a vertical line); (d) heat is discharged to atmosphere, receiver or condenser.

greater quantity of water must be handled, involving the expenditure of more power in the auxiliaries. A full appreciation of this point will be gained from Fig. 15.

EFFICIENCIES

It is of interest to note how the turbine has surpassed the

economies established by the most efficient reciprocating engines. This is indicated by the records of both engines and turbines, given in Tables III and IV. The best engine economies that have been published have been obtained by consulting the proceedings of engineering societies, and the most important tests are given in Table III, from which it may be seen that the most efficient engine has shown itself capable of developing a kilowatt-hour on about 17 lbs. of steam, with 175 lbs. pressure, 80 to 90 degrees superheat, and 28 inches vacuum. This engine record has been improved about 20 percent by the turbine, by reason of its ability to carry out the expansion of the steam more completely. One of the straight double-flow turbines of 10 000 kw capacity, installed by the City Electric Company, San Francisco, California, has developed a kilowatt-hour with 13.88 lbs. of steam under practically the same operating conditions.

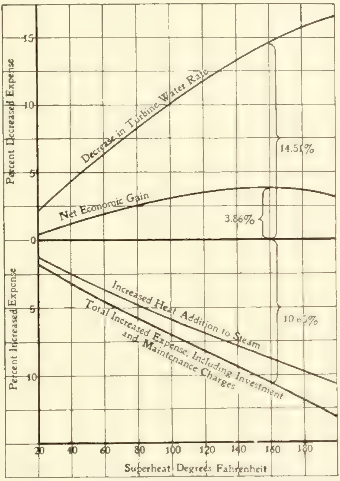


FIG. 13—ECONOMIC VALUE OF SUPERHEAT AT FULL LOAD OPERATION

Steam pressure, 175 lbs., feed water temperature, 210 degrees F., specific heat of superheated steam from Knoblauch and Jakob. Investment and maintenance charges per kw-hr. assumed equal one-half the fuel expense.

Unfortunately, statements regarding economy results are often made in which only the actual water rate is given without any reference to the operating conditions. Such unqualified statements regarding steam consumption are misleading and offer no means of comparison with other records. As no two machines operate under identically the same conditions, we must look for some measure of their performance. The Rankine cycle furnishes an adequate basis, which is the number of B.t.u. or energy available between the temperature limits of the steam. The ratio of the B.t.u. actually used by the engine or turbine to the amount theoretically available, is termed the Rankine cycle efficiency.

TABLE III—PUBLISHED TESTS OF RECIPROCATING ENGINES

Make of Engine	Station	Percent—Nominal Electric Load	H.P. Cylinder Diam. In.	L.P. Cylinder Diam. In.	Stroke—Inches	Steam Pressure at Throttle	Superheat at Throttle	Vacuum at Exhaust No. 2	Indicated Horse-Power	Total Steam per Ind. Hp.	Mech. Eff. / Gen. Eff.	Steam — Pounds per Kw-Hr.	Authority
McIntosh, Seymour and Company		25	31	64	48	136.	55.3	26.4	716	12.95			Prof. Lionel S. Marks. Transactions A. S. M. E. 1904
		50	31	64	48	132.	70.3	26.4	1196	12.22			
		100	31	64	48	136.	64.2	25.4	2184	12.50		18.62	
	Boston Edison and Cambridge	50	29	60	56	169.4	48.3	26.1	1229	12.58			
		75	29	60	56	167.	64.5	25.6	1831	12.71	86.	19.88	
		100	29	60	56	168.6	80.2	24.9	2267	12.72	90.	18.95	
		100	29	60	56	162.8	98.4	25.6	2202	11.57		17.23	
Westinghouse	New York Edison	75	44	76	60	186.1		26.9	1230	12.45	94.7	17.7	J. D. Andrew. Proc. N. E. L. A. 1904.
		100	44	76	60	183.1		26.36	5278	12.16		17.1	
		100	44	76	60	185.6		27.25	5442	11.93	95.	16.78	
Allis-Chalmers	Interborough	100	42	86	60	175.2		25.52	7365	11.96	92.5	17.34	Allis-Chalmers Bulletin
	Manhattan	100				175.		27.5	6000		92.5	17.41* 17.08**	H. G. Stott. Proceedings A. I. E. E.

*Equal cylinder work. **Unequal cylinder work.

TABLE IV—STEAM CONSUMPTION AND EFFICIENCY OF STEAM TURBINES

	Name	Load in Kilo-watts	R. p. m.	Boiler Pressure Lbs. per Sq. In.	Superheat Degrees F.	Vacuum 30-inch Standard	Water Rate Lbs. per Kw-Hr.	Rankine Cycle Efficiency	Authority
	AMERICAN.								
Reaction Westinghouse	New York Edison.	9 870	750	177.—	97.—	27.31	15.—	67.3	Operating Co.
	Brooklyn R. T.	11 466	750	177.—	106.—	28.15	14.45	65.72	Operating Co.
	City Electric Co., San Francisco, Cal.	9 173	1 800	167.—	59 —	27.9	14.57	69.—	J. G. White & Co. Tests
Impulse Curtis	New York Edison.	8 880		177.8	108.5	28.1	15.05	65.1	Geo. A. Orrok
	Commonwealth Edison.	10 186	750	176.—	147.—	29.47	12.9	62.1	Consulting Engineers
	Pacific Gas & Electric Co. . . .	8 775	750	179.3	72.95	28.03	15.95	61.0	F. H. Varney
	Boston Edison.	5 195		173.7	142.—	28.80	13.57	64.7	I. E. Moulthrop
	EUROPEAN.								
Reaction	C. A. Parsons, Carville.	5 059	1 200	194	92	29.27	13.35	62.9	Z. d. V. D. I. 1907, p. 1122
	C. A. Parsons, Chelsea.	6 000	1 000	190	140	28.00	14 09	65.8	Test results
	Brown-Boveri, Frankfurt.	3 522	1 360	142	136	28.92	13.68	65.8	Z. d. V. D. I. 1908, p. 516
Impulse	Escher Wyss Co., Essen.	5 118	1 025	146	158	27.63	15.16	65.1	Z. d. V. D. I. 1908, p. 1436
	Escher Wyss Co., Turin.	3 540	1 485	172	105	28.29	15.10	64.4	Z. d. V. D. I. 1908, p. 1437
	A. E. G. Moabit, Berlin.	3 169	1 500	170	217	29.19	12.74	63.5	Z. d. V. D. I. 1907, p. 386
	A. E. G. Rummelsburg.	4 239	1 497	173	285	29.19	11.90	65.1	Z. d. V. D. I. 1909, p. 762
	D. Howden & Co., Manchester. . .	7 520	1 000	184	133	27.55	14.50	67.0	London Engineer 1909, p. 462
	D. Howden & Co., Manchester. . .	6 383	1 000	188	137	27.44	14.30	67.6	London Engineer 1909, p. 462

Peabody's Steam Tables, 1909 Edition, used in calculating Rankine Cycle Efficiency on Kw-Hr. Basis.
Z. d. V. D. I.=Zeitschrift des Vereines Deutscher Ingenieure.
A. E. G.=Allgemeine Electricitats-Gesellschaft.

The engine develops its highest efficiency ratio in the high pressure ranges and the turbine in the low pressure ranges. This accounts for the fact that a combined unit exceeds the best results attained in either type. Substantial improvements can often be made in existing steam engine stations, condensing as well as non-condensing, by the introduction of the low pressure turbine and consequently remarkable progress has been made in this direction within the last few years. New stations are not usually built along these lines because other factors of power costs, such as labor and investment charges, must be duly considered in connection with the efficiency of the unit.

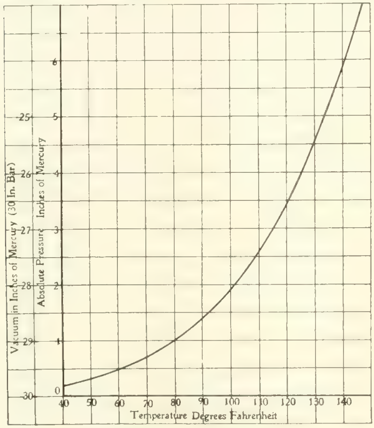


FIG. 14—PROPERTIES OF SATURATED STEAM AT LOW PRESSURES

Showing relation between temperature and pressure (Peabody).

Referring to the operation of complete expansion turbines, the best efficiency results on record are those of the double-flow construction,* viz., 69 percent. While many of the turbines included in Table IV indicate lower water rates, in no case is as excellent an efficiency found. With a better understanding of the economic value of operating conditions, as previously exemplified with concrete illustrations, it is believed that engineers will cease to give much weight to bare water rates.

TESTS

Many factors enter into the testing of a turbine, and consequently experience and care must be employed to ensure against errors in observations, which may indicate false results. Obviously an essential consideration is the correct measurement of the tur-

*Included in a paper read before the American Society of Mechanical Engineers by Mr. Samuel Naphtaly, December, 1910, and the accompanying discussion.

bine output, and with the precision obtaining in electrical science, meters thoroughly calibrated with standards and applied properly should, of course, introduce no errors. Similar precautions and reliability prevail with the steam measuring apparatus. Moreover, the discovery of Willans' Right Line Law, as applying to turbines, has proven very beneficial in verifying the accuracy of various test points at different loads. This law establishes the fact that the total steam consumption values for the turbine at various loads lie in a straight line. Hence it serves to disprove any results that fail

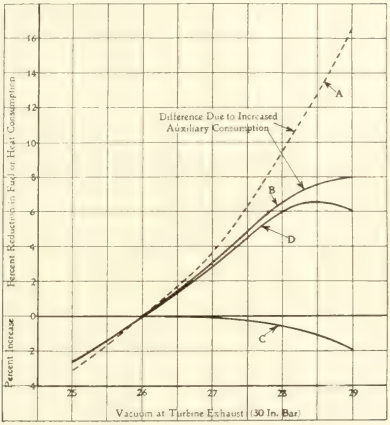


FIG. 15—RELATIVE VALUE OF DIFFERENT VACUA ON ULTIMATE PLANT ECONOMY

A—Actual reduction at the turbine.
B—Net reduction in plant fuel consumption.
C—Cost of obtaining the higher vacuum, including the greater fixed charges and maintenance.
D—Final plant improvement.

Based on 2 000 kw turbines using surface condensers supplied with injection water at an average temperature of 55 degrees F. Steam pressure 175 lbs., superheat, 100 degrees. Most economical arrangement of auxiliaries selected for each vacuum to give best heat balance. Investment and maintenance charges per kw-hr. assumed one-half the fuel expenses, burning $3.00 coal.

to rationalize with other tests that prove to be regular. Besides, when the readings are taken completely, the results may also be checked through thermodynamic relations. The neglect to verify observations has frequently led to the dissemination of more or less doubtful information.

On the other hand, tests may be conducted with entire certainty.* As an example, a test of a 600 kw non-condensing turbine generating unit† was made first by independent hydraulic brake measurements on the turbine, and by the separate loss method with the generator; these combined agreed with the over-all tests made afterward on the assembled unit. And as another instance, tests on two 1 000 kw turbines for the United States Navy Yards, authenticated by a Government representative, virtually agreed throughout their entire range of load. With large turbines tested after installation, the same uniformity of tests applies, as exemplified in tests of three 10 000 kw turbines at the Brooklyn Rapid

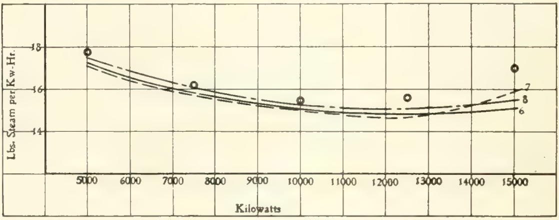


FIG. 16—TESTS ON THREE 10 000 KW TURBINES AT THE WILLIAMSBURG STATION OF THE BROOKLYN RAPID TRANSIT COMPANY.

Corrected to designed conditions—175 lbs. gauge pressure, 100 degrees F. superheat, 28 inches vacuum (30-inch barometer).

Unit No. 6 tested Dec. 1908, No. 7 tested Nov. 1909, No. 8 tested July, 1910. The circles represent the guaranteed performance.

Transit Company and given in Fig. 16. Only one point (150 percent overload) appreciably departs from the values established in other tests, and this, being the only one out of fifteen load tests, may be regarded lightly inasmuch as it does not conform with the characteristic performance of this design of turbine. At full-load the maximum variation from the mean is somewhat less than one percent in the three different machines, demonstrating emphatically the degree of accuracy obtainable both in construction and test of the turbine.

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*See discussion on "Steam Turbine and Turbo-Generator Testing" in the proceedings of the *American Institute of Electrical Engineers*, December 1910.

†See "Steam Turbine Progress," Railway Club of Pittsburg, May 20, 1910.

TESTING TRANSFORMER IRON LOSSES ON THE SINE WAVE BASIS

THOMAS SPOONER

CENTRAL STATION managers and, in fact, most users of transformers know the importance of low transformer iron loss, and many know that the wave shape of the terminal voltage affects the iron loss. With a given transformer, different iron losses will be obtained with different wave shapes of the impressed voltage, the measurements being made with the same instruments and under otherwise apparently similar conditions. In order, therefore, to obtain a comparison of transformers of various manufacture, the critical purchaser has been forced to resort to competitive tests under like conditions of wave shape, voltage, and frequency; or otherwise to demand that iron loss guarantees be made on a sine wave basis. Competitive tests are usually both expensive and inconvenient and are unnecessary if proper testing methods are employed. If the loss is measured, using an ordinary voltmeter, it may be claimed by the producer that when the loss is high it results from the use of a distorted wave and that a proper loss would have been found if a sine wave had been employed. Therefore a customer must have facilities for testing iron loss in terms of a sine voltage, in order to definitely decide whether transformers delivered to him are acceptable.

In a recent article* it was estimated that $4 000 000 are expended annually for iron losses in transformers. This enormous loss would probably have been expressed by a figure nearly twice as large except for the advent of silicon steel, the keen competition in transformer production, and the awakening of the central station manager to the importance of low iron losses in distributing transformers. This waste of useful energy must be watched and made as low as possible in every unit installed, since the loss goes on day and night during heavy load and at no-load. Beside being a direct expense, the iron loss, when excessive, will shorten the life of a transformer due to additional heating and roasting of insulation under heavy loads.

Several methods for obtaining corrected sine wave iron loss have been developed, and the present article will point out briefly

*Dr. M. G. Lloyd, *Journal of the Franklin Institute,* July, 1910.

various features of the three methods generally accepted as being the best. Of these methods, the one most recently developed has proven to be more accurate than the others. It is, moreover, much more convenient as regards time, labor and equipment, and the necessity of competitive tests is done away with. This method is based on the use of what is known as an iron-loss voltmeter, an instrument which indicates the voltage of a pure sine wave which will produce the same iron loss in a transformer as the voltage wave of the circuit to which it is connected *does* produce. In other words the voltmeter automatically enables the tester to so adjust the voltage that errors due to distortion of wave shape from the sine form are corrected. It also eliminates the necessity of close frequency regulation during the test. The readiness with which this simplified method may be applied and the accuracy obtainable in tests are evidenced by the records which will be described in some detail.

WAVE SHAPE AND IRON LOSS

The iron loss of a transformer consists of two parts, namely, the hysteresis loss caused by the cyclic magnetization of the iron, and the eddy current loss caused by the circulation of electric currents in the iron or steel core induced indirectly by the varying magnetic flux. The hysteresis loss is dependent upon frequency and the average value* of the voltage wave impressed upon the transformer winding. The eddy current loss is dependent upon frequency and the effective value of the voltage (r.m.s. voltage) impressed upon the winding. From this it is evident than an intelligible expression of transformer iron loss must give, besides the watt loss, the conditions under which the test is made. The frequency and normal voltage (r.m.s. voltage) are generally given, or are known from the rating of the transformer; the value of average volts is not given but today is understood to be equal to the effective voltage divided by the form factor of a sine wave. In testing transformer iron losses it is difficult to control these three testing conditions independently and get iron loss readings in terms of the standard sine wave; hence the value of a method which will give correct results in terms of normal frequency, normal effective voltage, and the normal form factor.†

*In this article the "average" voltage refers to the average of the instantaneous value of voltage for half of a cycle. The effective voltage, that ordinarily referred to in practice, is the square root of the mean square of the instantaneous value of voltages (root mean square).

†The form factor of a voltage wave is the ratio of the effective to the average voltage; for the sine wave this ratio is 1.11.

TESTING

Until recent years all commercial tests of transformer iron losses have been made by reading the open circuit input to the transformer with a set of instruments consisting of a wattmeter, an alternating-current voltmeter, (r.m.s voltmeter) and a frequency meter, tachometer, or some other frequency indicator. In a testing laboratory equipped with special instruments and auxiliary apparatus so that the tester can control frequency accurately and can transform or regulate the voltage of a good sine wave generator without distorting the wave form, satisfactory tests can be made. However, certain precautions may have been neglected or certain disturbing influences may exist during any test that will cause distortions of the voltage wave impressed upon the transformer, and without special means of measuring the voltage form factor or average volts, unavoidable errors of several percent may creep into the final result of iron loss. Circuits with pure sine wave voltage which are of sufficient capacity to test transformer iron losses are rare, and it is safe to say that even on such circuits sine wave voltage at the terminals of a transformer under test rarely exists, on account of the combined distorting effect of the resistance and reactance in the line, alternator armature, and series coil of the wattmeter. In order then to determine the performance of a transformer it is necessary to make the iron loss test by a method in which wave shape correction can be made, or one that will give the sine wave loss directly.

Two prominent methods of correcting for errors of form factor are as follows:

In the first, an oscillogram of the voltage wave is taken under the testing conditions, and from it the form factor of the wave is worked out. The result is used to correct the hysteresis component of the watt-loss observed at normal (effective) voltage. This method was carefully tried out with a General Electric Oscillograph using both the synchronous tracing table and photographic films. The results obtained were in all cases within commercial limits of accuracy.* Needless to say, this method is too expensive and requires too much time and equipment to be used in commercial tests.

The second method consists of rectifying the voltage wave with a synchronous commutator and reading the average voltage with a

*For details of this method and results obtainable see article in the *General Electric Review* for Jan., 1909.

direct-current or permanent magnet voltmeter. This method will give very accurate results when a well constructed commutator is used. The author used a small hard rubber commutator with copper segments. Accurate work by this method depends upon perfect rectification of the wave of voltage so that it is necessary to direct-connect the commutator to the generator or drive it with a synchronous motor which does not hunt. Both methods of drive were tried with about equal accuracy. The results, however, were not comparable with those obtained by Dr. M. G. Lloyd and published in an able article on the subject.†

FIG. 1—IRON LOSS VOLTMETER

A third method, that of using an iron loss voltmeter, has lately been tried out by the writer, and the accuracy, ease and quickness of the method for making commercial tests of core losses were surprising and seem to warrant special comment.

A brief description of the function, construction and method of using the iron loss voltmeter will serve to make clear the test data which is to follow. The complete meter is shown in Fig. 1, and a diagram of the parts and electrical connections is shown in Fig. 2. A laminated core of silicon steel *A*, is wound with a coil *B*. This coil is connected to the binding posts *C* through the series coils *D* of a Kelvin type wattmeter movement. The shunt circuit consists of a non-inductive resistance *E*, two movable coils *F*, and four adding coils *G* which contain the same number of turns and are wound with the corresponding stationary series coils. In reality then the instrument is, in effect, not a voltmeter but a

†*Bulletin of the Bureau of Standards*, Vol. IV., p. 477.

wattmeter measuring the total loss in the steel core and the copper circuits of the instrument.

With the terminals of the shunt circuit connected as they are, and with the adding coils to carry the shunt current around the stationary field coils, the torque or indication of the meter will be influenced by al! copper and iron losses in the instrument. There are two scales on the instrument, one marked volts and the other watts. The former is obtained by connecting the instrument in parallel with an ordinary voltmeter to a circuit having a pure sine voltage and given frequency. The volt scale of the iron loss voltmeter is then carefully calibrated to agree with the standard voltmeter. The second or watt scale indicates the total watt input to the instrument and is a great convenience in testing, as it enables the instrument loss to be obtained without any calculation. Before calibrating the instrument the proportion of eddy current and shunt

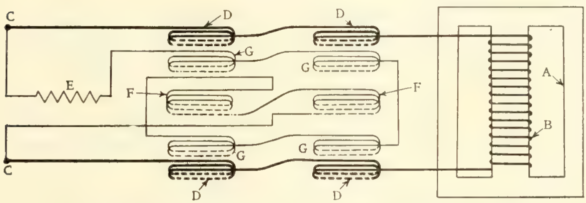


FIG. 2—DIAGRAM OF CONNECTIONS OF IRON LOSS VOLTMETER

copper loss to hysteresis is adjusted so as to correspond with that of the average transformer.

In measuring iron loss the use of the instrument represents strictly a substitution method and the following assumed tests will serve better than a theoretical analysis to show how the instrument automatically corrects for wave shape errors. Assume a transformer and a wattmeter to be connected to a circuit in such a way that the wattmeter indicates the iron loss in the transformer. Suppose also that an iron loss voltmeter and an ordinary alternating-current voltmeter are connected across the terminals of the transformer. The wattmeter reading will now also include the losses in the two voltmeters. If a pure sine wave voltage is impressed upon the transformer, both instruments will agree and read say 110 volts. If the wattmeter reads 130 watts, the iron loss meter 25 on the watt scale, and the copper loss in the other volt-

meter is found by calculation to be five watts, it may be concluded that the 110 volt sine wave iron loss of the transformer is 130 — (25 + 5) = 100 watts. Next, suppose the testing wave to be peaked (high form factor) so that at 110 volts (effective) the iron loss is four percent low. In this case the two voltmeters will not agree and, since the input to the iron loss voltmeter follows the same laws as the iron loss in the transformer, its internal loss will also be four percent low and the meter will indicate *24* on the watt scale. Under these conditions the wattmeter will indicate 125 watts and the iron loss of the transformer will be 125 — (24 + 5) = 96 watts, which is four watts below the sine wave value. If the voltage is now raised until the iron loss voltmeter again reads *110* on the volt scale, it will read *25* on the watt scale and the loss in the transformer will also be raised to the value of 100 watts, which is the sine wave loss for 110 volts as indicated by the iron loss voltmeter. The reading of the ordinary voltmeter will be higher than 110 volts in this last case. In case a flat wave (low form factor) is used in the test, the iron loss voltmeter will read higher than the ordinary instrument and also, with the latter reading 110 volts, the loss in the transformer will be higher than the sine wave value. If the voltage is lowered so that the iron loss voltmeter reads 110 volts, the input to the transformer will again be 100 watts, the true sine value.

Variation of frequency from the normal value will affect the loss in the iron loss voltmeter in the same way that it will the transformer iron loss. Frequency errors are therefore automatically corrected for by the instrument in the same way that the wave shape errors are corrected.

Tests of the accuracy of the method have recently been made under commercial and also under abnormal conditions. The laboratory was equipped with a four-pole, 60 cycle, smooth-core, inverted rotary converter to the shaft of which was coupled a 12 pole revolving field booster, the armature of which was connected in series with that of the converter. This "stationary" armature could be rotated by a tangent screw and the field strength of the booster was adjustable between wide limits. From this it is evident that a third harmonic voltage of any reasonable magnitude and with any phase position with respect to the fundamental could be superimposed upon the normal wave of the 60 cycle machine. By this means the form-factor of voltage could be varied at will.

A transformer, wattmeter, iron loss voltmeter, and root-mean-square voltmeter were connected in circuit as shown in Fig. 3, and tests were made at 60 cycles with different form factors. Iron losses were measured by both the old and the new method on each different wave of voltage. First, results were taken with the iron loss voltmeter reading 110 volts. The voltage was then adjusted until the root-mean-square voltmeter read 110 volts and another reading of iron loss was taken. An oscillograph tracing was taken of each wave shape used and from it the form factor of the wave was worked out. In each test the instrument losses were subtracted from the wattmeter reading and the result was the iron loss for the particular test. Tests *1* to *7* inclusive, Fig. 4, show the waves that were used. With each oscillogram the corresponding form factor, iron loss results, and errors are given for the iron loss voltmeter method and for the usual method employing a volt-

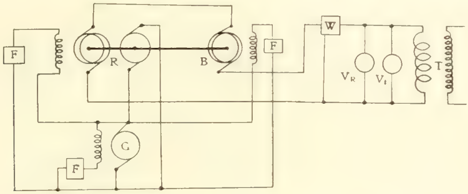


FIG. 3—DIAGRAM OF CONNECTIONS FOR COMPARATIVE TEST
T—Transformer; *G*—direct-current generator; *R*—inverted rotary converter; *B*—harmonic booster; *F*—field rheostats; *W*—wattmeter; *Vr*—root-mean-square voltmeter; *V*I—iron loss voltmeter.

meter reading effective volts. The curves of Fig. 5 show graphically the errors of the test results obtained by the two methods.

Test *1*, Fig. 4, includes an exciting current curve. Test *6* has a form factor which approximates very closely the normal or sine wave form factor, although the wave is very distorted. Test *5* is the voltage wave of the rotary converter without the booster. Its wave of voltage is of almost pure sine form. It is to be noted that even with the very abnormal wave of test *1*, having a form-factor of 1.66, the iron loss voltmeter test was only 1.7 percent in error while the ordinary test gave an error of 24.8 percent. This test also illustrates a condition for which the iron loss voltmeter automatically compensates, but which would be very difficult to allow for by any other means. It will be seen that the voltage wave passes

Iron Loss Vm. Method (Curve A, Fig. 5.)	R. M. S. Vm. Method (Curve B, Fig. 5.)
I.L. Vm. Reading . . 110.0	R.M.S. Volts 110.0
(R.M.S. Volts . . . 130.7)	(I.L. Vm. Reading. 91.9)
Core Loss 95.8	Core Loss 70.8
Percent Error . . . . +1.7	Percent Error . . . . −24.9
Form Factor 1.66	Form Factor 1.66
I.L. Vm. Reading . . 110.0	R.M.S. Volts 110.0
(R.M.S. Volts . . . . 125.5)	(I.L. Vm. Reading. 95.8)
Core Loss 95.0	Core Loss 73.9
Percent Error . . . . +0.85	Percent Error . . . . −21.6
Form Factor 1.38	Form Factor 1.38
I.L. Vm. Reading . . 110.0	R.M.S. Volts 110.0
(R.M.S. Volts . . . . 120.1)	(I.L. Vm. Reading . 100.3)
Core Loss 94.6	Core Loss 80.5
Percent Error . . . . +0.42	Percent Error . . . . −14.5
Form Factor 1.225	Form Factor 1.225
I.L. Vm. Reading . . 110.0	R.M.S. Volts 110.0
(R.M.S. Volts . . . . 114.6)	(I.L. Vm. Reading. 105.3)
Core Loss 94.2	Core Loss 86.8
Percent Error 0.0	Percent Error . . . . −7.86
Form Factor 1.164	Form Factor 1.164
I.L. Vm. Reading . . 110.0	R.M.S. Volts 110.0
(R.M.S. Volts . . . . 110.0)	(I.L. Vm. Reading. 110.0)
Core Loss 94.2	Core Loss 94.2
Percent Error 0.0	Percent Error 0.0
Form Factor 1.110	Form Factor 1.110
I.L. Vm. Reading . . 110.0	R.M.S. Volts 110.0
(R.M.S. Volts . . . . 110.2)	(I.L. Vm. Reading. 109.8)
Core Loss 94.6	Core Loss 94.4
Percent Error . . . . +0.42	Percent Error . . . . +0.21
Form Factor 1.113	Form Factor 1.113
I.L. Vm. Reading . . 110.0	R.M.S. Volts 110.0
(R.M.S. Volts . . . . 107.3)	(I.L. Vm. Reading. 112.8)
Core Loss 94.8	Core Loss 99.6
Percent Error . . . . +0.64	Percent Error . . . . +5.73
Form Factor 1.054	Form Factor 1.054

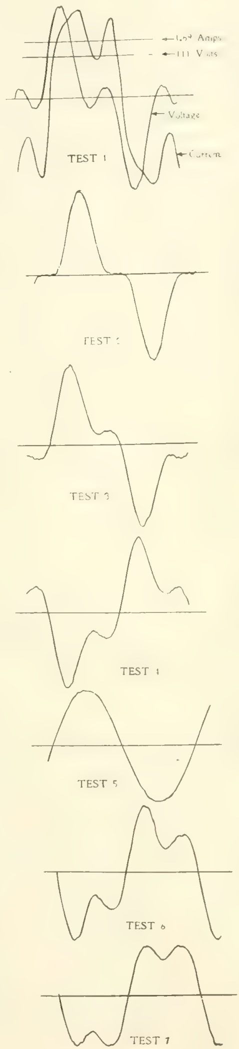


FIG. 4—OSCILLOGRAMS WITH TEST RECORDS

through zero four times more per cycle than is the case with the ordinary wave. This means that the flux wave has a dimple in it and hence a minor loop is introduced into the hysteresis loop. This produces a greater loss than would otherwise occur. It should be noted that this minor loop occurs both in the core of the iron loss meter, thus affecting its reading, and in the transformer core. The corresponding current wave is also shown in this oscillogram

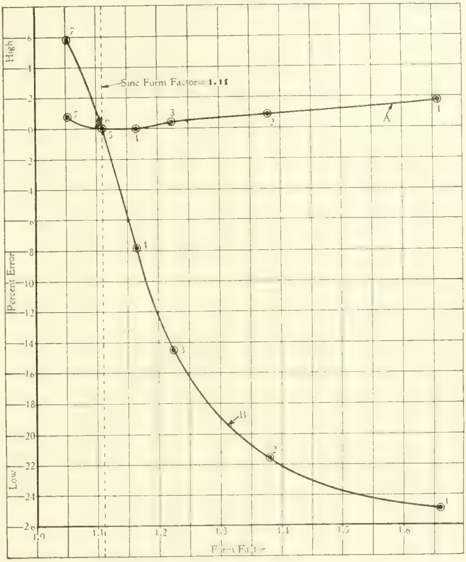


FIG. 5—CURVES SHOWING RELATION BETWEEN FORM FACTOR OF VOLTAGE WAVE AND PERCENT IRON LOSS ERROR

A—Iron loss voltmeter method of measurement; *B*—root-mean-square voltmeter method.

The iron loss voltmeter inherently compensates for errors in measurement due to form factor.

to bring out this fact more clearly. At the moment at which this minor loop occurs, it is seen that the magnetizing current drops to almost one-half its maximum value and then returns to nearly its original value. The marked bending at the bottom of curve *B*, Fig. 5, is doubtless partly accounted for by this effect. Thus the iron loss voltmeter inherently compensates for the effect,

otherwise the error with the ordinary voltmeter would have been much greater in test *1*. Test *6* brings out an interesting feature. This particular wave, although very much distorted, is found to have practically the same form factor as a sine wave; with this wave form of voltage, transformers might be accurately tested with an ordinary voltmeter. Test *7* shows practically the minimum form factor which can be obtained by introducing simply a third harmonic into the fundamental. If the amplitude of the harmonic is increased or decreased, the form factor increases.

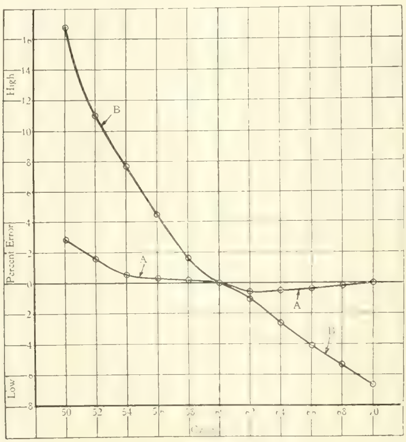


FIG. 6—CURVES SHOWING RELATION BETWEEN FREQUENCY AND PERCENT IRON LOSS ERROR

A—Iron loss voltmeter method; *B*—root-mean-square voltmeter method.

With ordinary commercial frequency variations no appreciable error occurs when using the iron loss voltmeter, as shown by curve A.

The waves shown in the tests seem more distorted than those found in practice. This is due to the fact that the form factors were varied from maximum to minimum by shifting the phase relation of a relatively large third harmonic from the position of maximum peaking (test *2*) to one giving maximum flattening (test *7*). Service conditions would have been more nearly reproduced if the symmetrical wave of test *2* had its harmonic component reduced to zero, reversed, and increased so as to get successive steps between

tests *1* and *7*. Such a variation of the wave shape would give tests with symmetrical waves but the range of form factors and test results would be unchanged.

The curves of Fig. 6 show the errors introduced by changes of frequency. The comparatively large errors at 52 and 50 cycles with the iron loss meters are due to the excessive copper loss in the coils of the transformer caused by the abnormally large exciting current which is a characteristic of silicon steel operated at high induction. It is evident from these curves that no attention need be paid to the frequency in making iron loss tests with an iron loss voltmeter, for the frequency of a given circuit will never vary sufficiently from the normal value to introduce appreciable iron loss errors.

No attempt was made to obtain data on the effect of differences in hysteresis exponents in the transformer and the meter, as such tests would be rather difficult to make. However, it may be shown by a few simple calculations that the possible error due to this cause is entirely negligible for any conditions which are likely to occur. It should be understood that in practice the oscillograph and ordinary voltmeter are not required in making tests. They were used in the tests illustrated simply to show a comparison with the old method and to show the voltage wave used in making the comparison.

The complete outfit required to test iron losses by the iron loss voltmeter method simply consists of an iron loss voltmeter and a wattmeter. No errors of frequency or wave shape need be measured or even considered, and no special precautions need be taken in conducting tests. In all cases the result will be the equivalent iron loss for a sine wave shape and normal frequency, and the test obviously can be made more quickly and easily than the customary iron loss tests using an ordinary alternating-current voltmeter. Such a method should appeal at once to the man who has transformer testing to do; it should rapidly do away with the competitive testing of transformer iron losses, and should enable the producer and consumer of transformers to understand each other when the iron loss of a transformer is under discussion.

WINDING OF DYNAMO-ELECTRIC MACHINES—XI

FIELD COILS

J. L. SMITH

FIELD coils in both generators and motors are subject to mechanical stresses from various causes. Vibration, produced by an engine, belt, or driven machine, and, as in the case of traction motors, by actual jolting of the whole motor, tends to disintegrate the coil insulation if it is at all brittle, and to chafe the materials if any motion is possible. The magnetic reaction between field coils and armature tends to pull the coils away from the pole pieces, thus producing stresses at the points of support. Adjacent conductors inside of a coil tend to draw together, while conductors on opposite sides tend to separate, thus causing a tendency to make the coil bulge. Heating tends not only to weaken the insulation, but on a large coil may cause the layers to crawl along one another, doing mechanical damage to the insulation between turns unless this action is prevented by suitable construction. In fields of the rotating type the centrifugal action tends to throw the coils off the poles, this stress being so much greater than the magnetic reaction having the same tendency that the latter may be neglected. In addition, the change in stress as the machine is brought up to speed and the excitation started, is very liable to cause motion of the coils unless they are rigidly braced.

The coils must, of course, be suitably insulated to prevent breakdown between turns, and from the coil to the frame of the machine. The voltage to be withstood consists not alone of the normal excitation voltage required to produce increased generator potential under overload conditions, but the excessive voltages occasioned by opening the field circuit without a discharge resistance, or by starting synchronous apparatus from the alternating-current side. This voltage must be withstood at times under the most adverse conditions of dirt, oil and moisture, and the insulation is selected with this necessity in view.

In addition to the electrical and mechanical characteristics which are absolutely essential for a field coil, other characteristics are very desirable. Thorough ventilation is essential to high efficiency and low cost. Large, thick coils, with the copper imbedded in a mass of insulation, are precluded. The ideal is to have the bare copper exposed to the air on all sides. This has been practically attained in certain types of series coils and strap coils for rotating

field machines, and partially attained in strap wound shunt coils. Economy of space is always desirable, and in railway and similar types of motors is of the utmost importance. Cost features require that the coil shall be easily wound, insulated and installed, and, when necessary, readily removed for repairs.

To meet the various requirements of voltage, size, and conditions of service, a great variety of field coils is necessary. These may be most conveniently classified according to their method of winding.

WIRE COILS

Shunt coils for the smaller machines and for the higher voltages of fairly large machines are wound on moulds from round or square wire, which is nearly always cotton covered, tension being supplied by a form of friction brake on the reel from which the wire is taken. The end turns of each layer are usually supported by strips of tape or paper or by cord so placed as to lap around them and be held by the turns at the center of the coil. The wire is usually wound alternately right and left, much as thread is wound on a spool. Where the voltage per layer is high, this construction produces an excessive strain on the cotton insulation. In such cases a strip of paper or cloth is laid between the layers of wire for about half their length, or the end of the last turn is insulated and carried completely across the coil, all layers being commenced from the same end. Where coils are wound from heavy wire under considerable tension, the layers are protected from mechanical injury at the corners by strips of heavy paper.

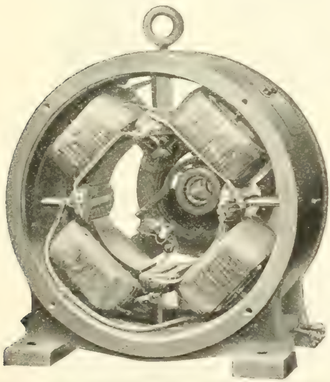


FIG. 125—SHUNT AND INTERPOLE COILS FOR 30 HORSE-POWER DIRECT-CURRENT MOTOR

The shape of the coil is frequently rectangular, with rounded corners, and with all the layers having approximately the same number of turns, as shown in Figs. 125 and 126. Due to limitations of space, one edge of the coil may be beveled off, or the coil may be of a wedge shape by making the layers gradually shorter at

one end, thus producing a stepped appearance as shown in Fig. 127. The coils are usually flat, but are sometimes rounded to conform to the shape of the field yoke. Such coils may be wound flat, and then pressed into the rounded form after winding, or may, especially if of heavy wire, be wound on curved moulds.

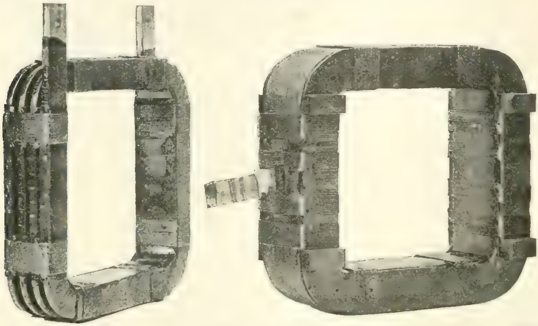


FIG. 126—SHUNT AND SERIES COILS FOR 250 HORSE-POWER DIRECT-CURRENT MOTOR

Joints in the wire are avoided whenever possible. When joints are necessary, they are of the wrapped or sleeve type and are as unobtrusive as possible. When suitable welding apparatus is avail-

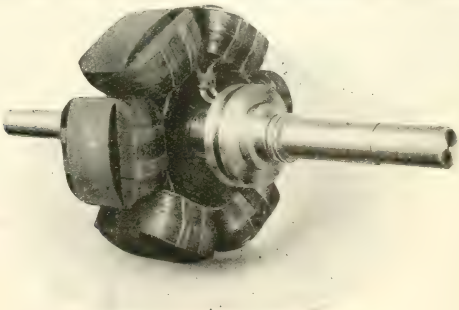


FIG. 127—ROTATING FIELD FOR 50 K.V.A. GENERATOR OR SYNCHRONOUS MOTOR

able, an electrically welded butt joint is very satisfactory on the larger sizes of wire and for copper strap. The joint is filed smooth, to remove all sharp corners, and taped so as to have the same insulating value as the rest of the wire.

The wire from which the coils are wounded is liable to break

off if subjected to vibration or bending. For this reason the ends are tied in place in the coil, and leads of stranded wire or strap copper are soldered on and brought to the outside of the coil. The lead from the inside is always crossed over the body of the coil, so that no connections are made close to the iron. The terminals for coils of large size are usually made from thin copper leaf to avoid bulkiness in crossing the coil.

FIG. 128—SERIES AND INTERPOLE COILS FOR 50 HORSE POWER RAILWAY TYPE MOTOR

Wire wound coils have generally been taped over the outside to provide mechanical protection to the coil. The present tendency, however, is to use as little outside covering as possible, in order to provide maximum ventilation, the coils being simply taped or corded

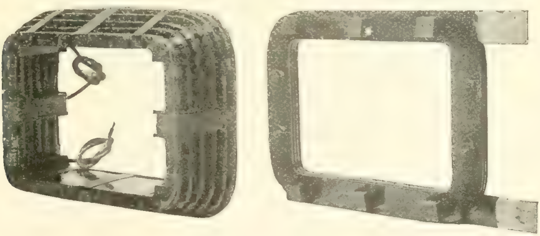


FIG. 129—SHUNT AND SERIES COILS FOR 600 KW DIRECT-CURRENT GENERATOR

in a few places to hold the strands in shape, as shown in Fig. 126. In such cases, extra insulation is supplied on the inside faces of the coil to protect it from grounds.

After being taped or tied, the coils are placed in a tank in which the temperature is raised to a high degree and the air exhausted, thus removing the moisture and air from the coils. A moisture-proof insulating compound in liquid form at high tempera-

ture is run into the tank until the coils are immersed; air is then readmitted to the tank under pressure, forcing the compound into all parts of the coils. The melting point of the compound is higher than any temperature the coils are liable to reach in operation, so that under normal conditions they form solid and absolutely waterproof units. This compound is so selected as to be a good conductor of heat, and thus assists materially in maintaining a low operating temperature. A final coating of hard, waterproof varnish gives a good wearing surface which is easy to keep clean.

FLAT STRAP COILS

A very compact and solid construction for both series and shunt coils consists of bare strap copper wound in a mould with strips of paper or asbestos between the turns. This type is used very extensively for railway type series coils, and for shunt coils

FIG. 130—EDGE-WOUND STRAP FIELD COIL FOR 200 K.V.A. ROTATING FIELD GENERATOR

on large direct-current generators and rotary converters. On railway motors comparatively heavy copper is used with one or more strips of asbestos between turns. Two such coils, wound in opposite directions, are usually placed one above the other with insulation between. The inside ends are connected together, leaving the ends of the complete coil at the outside, to avoid the necessity for crossing the leads over the coil. One of the individual coils is frequently wound with fewer turns than the other, and the space between them filled with triangular shaped insulating filler, producing beveled corners, and thus allowing a better space factor inside the motor.

Railway type coils, on account of the necessity for rigid bracing and protection against the constant jar and vibration, are tightly wound with heavy cotton tape. The leads are of heavy flexible cable in some types and in others are brought out to brass con-

nectors, tied to the body of the coil, as shown in Fig. 128. The coils are then vacuum impregnated and varnished.

This same type of construction, with much smaller strap, is used for shunt coils in large generators and motors. The coils are wound with paper between turns, tied with cord or tape, and impregnated. Several of the coils are then assembled, as shown in Fig. 129, arranged alternately right and left, spaced by wooden spacers, but without any other insulation between the layers. The

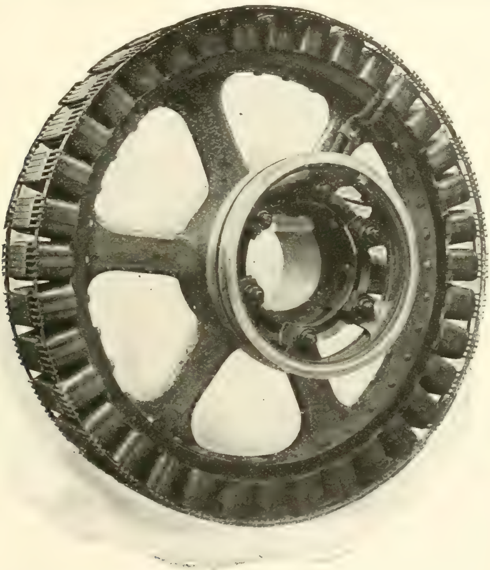


FIG. 131—ROTATING FIELD FOR 200 K.V.A. SYNCHRONOUS MOTOR
Rotor equipped with coils of the type shown in Fig. 130, and with squirrel cage starting winding.

spacers are so arranged that the air has free circulation through the coil parallel to the shaft only, so that the ventilating air is always fresh and cool. The inside and outside of adjacent coils are connected together, so that no crossing of the coil with leads is necessary, the ends of the complete coil coming at the outside end of the first and last layer of a coil with an even number of layers. Leads of flexible cable are usually soldered to the ends of the coil to prevent breakage. Wooden spacers prevent motion of

the coils sideways on the poles, and the coils fit snugly against the pole pieces circumferentially, being separated therefrom by varnished paper or other suitable insulation.

FORMER WOUND COILS

The centrifugal strains on rotating field coils require special precautions to prevent chafing of the insulation. Specially reinforced wire wound coils have proven very satisfactory, and are used in some cases. A coil wound with copper strap on edge, as shown in Fig. 130, is ideal for this service, as it is practically incompressible, and every turn is exposed to the air, so that the heat is readily dissipated.

These coils are wound on a former of special construction so that the copper strap may be bent edgewise without crinkling. They are then annealed, and all rough edges carefully removed. Asbestos strips are placed between the turns, together with a binding shellac, and the entire coil is compressed in a press and subjected to sufficient heat to drive off all moisture and combustible material. The coil is carefully insulated from the pole pieces, but no insulating material is placed over the outside. All the coils are formed alike, but have the leads arranged so as to be alternately right and left, the connections between coils coming alternately at the top and bottom, as shown in Fig. 131.

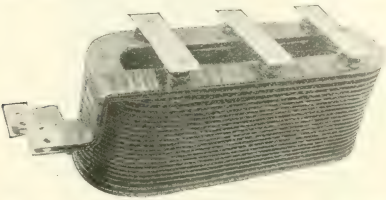


FIG. 132—INTERPOLE COIL FOR 600 KW DIRECT-CURRENT GENERATOR

Compound and interpole coils for direct-current generators and large motors are practically always of the strap-on-edge type, with adjacent turns separated by spacers. Industrial motors, which are liable to be subject to moisture and dirt have the individual turns taped altogether, as shown in Fig. 125, or separately, as in Fig. 126; other types have the end turns taped as in Fig. 132 to decrease surface leakage, while on many types no taping is done whatever, as shown in Fig. 129. The spacing of the turns may be done by wooden or fiber blocks, as shown in Fig. 126, or by insulated bolts, with insulating washers between turns, as shown in Figs. 129 and 132. Where great conductivity is desired, rather than use copper of excessive cross-section, several turns are connected in parallel, as shown in Figs. 132 and 133.

No impregnation is necessary with the strap-on-edge coils of either open or closed type, as no absorbent insulating materials are used. They are shellaced to a black, glossy surface, which is moisture repellant and is easy to clean.

TESTING

No elaborate tests are required for field coils. Usually wire wound coils, especially those with many turns of fine wire, are tested for open circuits by a test lamp or magneto. If a break is found, it is usually due to a faulty connection at the joint with the

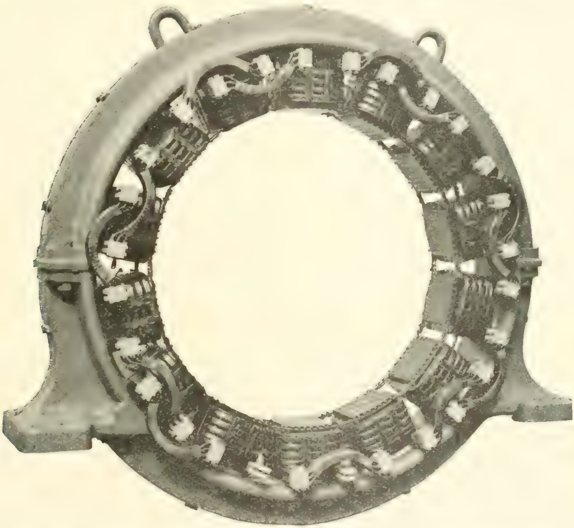


FIG. 133—FIELD COILS FOR 750 K.V.A., 250 VOLT ROTARY CONVERTER

flexible terminal, which can be remedied without rewinding the coil. If the tension on the reel during winding has been too great, the wire may be broken in one or more places but held by the insulation. This will show up in test, and the coil must be rewound.

The test for short-circuits consists in placing the coil over a laminated iron core, which is magnetically excited by an alternating current. Sufficient current will be generated in a short-circuited turn to cause severe local heating, which can readily be detected. As a further test and check on the winding process, the resistance of the coil is measured both hot and cold, to determine whether the specifications have been met in this regard.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal Box 911, Pittsburgh, Pa.

535—Series vs. Parallel and Lap vs. Wave Windings—*a*—In the design of direct-current generators and motors when and why are series and parallel armature windings used? *b*—In a motor-generator set comprising a 9 000 volt, 25 cycle, Y-connected motor and a 4150 volt, 60 cycle, Y-connected generator with grounded neutral, a lap winding is used in the motor armature while a wave winding is used in the armature of the generator. Why? D. D. H.

a—The form of winding used depends upon the characteristics and size of the apparatus. Generally speaking, the limitation of the series winding is the amount of current which can be carried by one armature circuit. A direct-current "series" winding consists of two circuits, therefore the current per circuit is in this case equal to one-half of the total armature current of the machine. Where the value of this current exceeds what has been found consistent with good practice, then it becomes necessary to arrange more circuits on the armature, each circuit carrying part of the total current. In this case the "parallel" winding is usually resorted to. As is well known, this winding is one having a number of circuits equal to the number of poles of the machine. However, the choice of series or parallel windings is usually not only determined from the amount of current to be handled but is greatly influenced by considerations of commutation and mechanical design—points requiring as careful attention as that of the amount of current to be handled. *b*—The alternating-current lap and wave windings used in the case cited are adopted purely for mechanical reasons. It is customary with some manufacturers to use wave windings wherever the current to be handled permits the use of a conductor of sufficient size to form it into a wave-shaped coil and where the number of coils in the slot does not become too large, this being objectionable on account of space required for insulating these coils. Other manufacturers employ the lap winding wherever possible, that is, in cases where the number of turns per slot does not become too small. As a general rule it can be said that the wave winding often works out to advantage in cases of comparatively large machines for low voltage, whereas the lap winding is preferable in cases of large or small machines for high voltage as well as for small machines for low voltage. J.B-W.

536—Multiple Operation of Synchronous Converter and Motor Generator—We have a 300 kw synchronous converter, a 200 kw engine-driven generator and a 300 kw motor-generator furnishing power to a 550 volt direct-current railway circuit. The motor-generator is provided with inter-poles. The characteristics of the three machines are as shown in Fig. 536 (a). We desire to obtain a better division of the load on the motor-generator and the converter, but are not particular about the engine-driven generator. You will note from the characteristics of the two 300 kw machines that on light load the voltage of the motor-generator is higher than that of the converter, but as full load is approached it drops off very rapidly while that of the converter drops off very slightly. We wish to adjust the shunt on the motor-generator so as to

give it a characteristic more similar to that of the converter, but we fear that if the shunt is adjusted so as to give almost equal compounding at full load, then the voltage of the motor-generator on light load will be much above that of the converter and make adverse operating conditions. How should these two machines be compounded for multiple operation? The commutation on the motor-generator seems to be poor, sparking being excessive at full-load. What is the function of the inter-pole? B. M. C.

It is assumed that the generator of the motor-generator set and the synchronous converter are compound wound and are properly connected by means of the equalizer leads. As the two machines operate at present, the converter takes more than its share of the load at full-load and above. To secure better parallel operation the characteristics of the converter will have to be changed to more nearly approximate those of the direct-current generator. Ordinarily, the series field of the converter should be shunted in order to give it more of a drooping voltage characteristic. Shunting its series field, however, shunts the series field of the generator as well. Therefore, in addition to shunting the series field of the converter, a small resistance should be placed in the equalizer lead. This resistance will prevent the shunting of the generator field and may remedy the trouble. However, this method can not always be applied. A theoretically correct method of adjustment is to insert a resistance in the series field of the machine. See article on "Parallel Operation," by Mr. H. L. Beach, in the JOURNAL for Nov., 1909, p. 681, and Nos. 352 and 424. Still another way to take care of the condition would be to reverse the series field of the converter, thus bucking the shunt field, and to shunt the series field sufficiently to prevent too much of a drooping characteristic. It may be necessary, in order to obtain the desired results, to insert additional reactance in the alternating-current circuit of the converter. This will depend upon the amount of reactance now in the circuit and cannot be determined without having complete information regarding the apparatus that is in the circuit. The function of the inter-pole is to give a fixed neutral position for the brushes at all loads. This neutral position is maintained constant by the inter-poles and the inter-pole windings which are placed in series with the armature and whose strength is thus proportional at all times to the armature current. To secure proper results from inter-poles two things are necessary. *a*—The inter-pole winding must be of the right strength. *b*—The brushes must be set on the right position, which is the mechanical or no-load neutral of the machine. Inter-pole coils are usually wound with ampere-turns slightly in excess of actual requirements and a small shunt is used for securing just the right current in the inter-pole winding. The peculiar droop in curve *B* is probably due to the action of the governor of the engine driving this unit.

J. B-W. & W. A. D.

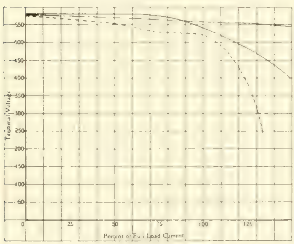


FIG. 536 (a)—REGULATION CURVES
Full line = motor-generator; 300 kw.
Broken line — engine No. 4 generator; 200 kw.
Dot-and-dash line = converter; 300 kw.

537—Connections for Oil Switch Trip Coils—In a three-phase—four-wire system a third overload trip coil has been added on the oil switches. Would this be necessary on a balanced load of otherwise? C. B. P.

Only two trip coils are required if the series transformers are Z-connected. Trip coil No. *1* protects against overload on lines *A* and *B*, and trip coil No. *2* protects against overload on *B* or *C*. It will be found, also, on careful examina-

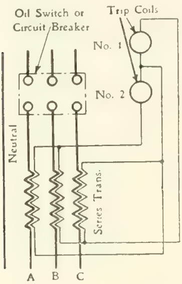
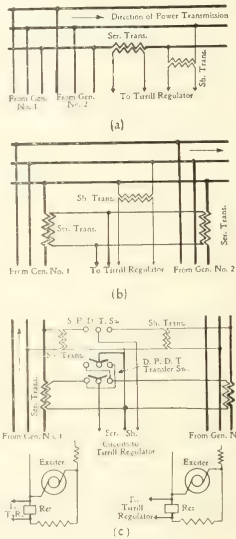


Fig. 537 (a)

tion of this diagram, that in case of ground or short-circuit between any two lines, the two trip coils furnish complete protection. See discussion and reference regarding the Z-connection in No. 97.

538—Connections for Operating Either of Two Alternators with a Single Tirrill Voltage Regulator—Two alternators, one a turbo-generator of 800 k.v.a. and the other an engine type unit of 100 k.v.a. capacity, provided with separate exciter units supply power and lighting load in a factory and in an adjacent town. Ordinarily the main generators will not be operated in parallel, however, they may be at times. It is not probable that there will be occasion to operate the exciters in parallel. A Tirrill regulator is provided for use primarily in connection with the 800 k.v.a. alternator. It is desired, however, to provide such additional switchboard connections as may be required to make it possible to use the regulator in connection with the 100 k.v.a. alternator when the larger machine is shut down, at times of light load such as occurs during part of the night. Both units can be arranged for connection to bus-bars, so that one voltage transformer will be sufficient, but it is presumed that a series transformer of suitable capacity will be required. Please indicate such switches or other devices as will be needed and show arrangement of circuits. L. S. H.

It is not obvious from the question where it is proposed to locate the series transformer. However, the desired results can be obtained by one of the three



Figs. 538 (a), (b) and (c)

following methods of connection, the one most applicable being dependent upon the arrangement of connections between two alternators and the bus-bar. If a series transformer can be located as in Fig 538 (a), and both generators are on the same side of the series transformer, no transfer switch is required to connect to one or the other generator, because the one

series transformer takes care of the entire load. Connection to the shunt and series transformers could then be made as shown in the diagram. If, however, both generators are permanently connected to the same bus-bars but it is not convenient to put the series transformers on the bus-bars, e. g., because of their size, connections can be made as in Fig. 538 (b). It will be noted that the series transformers on the two generator circuits are connected in parallel and that taps are brought out from the parallel connections for the Tirrill regulator. This connection could be used only where the line leading from the generator to the bus-bar, or some portion of this line, is used exclusively for this connection. If it is not possible to locate the series transformers, as in Fig. 538 (b), in such a place that they will receive the current only when it flows to the bus-bar in question, connections may be made as in Fig. 538 (c). Here a two-pole transfer switch is required. When this switch is thrown to the left, the left-hand series transformer is connected to the Tirrill regulator and the right-hand series transformer is short-circuited. When the switch is thrown to the right, the right-hand series transformer is connected to the Tirrill regulator and the left-hand transformer is short-circuited. Fig. 538 (c) shows also a single-pole, double-throw switch for changing the shunt connections from one line to the other. This switch is not necessary in case only a single shunt transformer is required, which may be connected to the bus-bars. H. W. B.

539—Number of Transformers Required for Compensator on Three-Phase Circuit—We have been operating a 200 kw, three-phase generator in our station for some time as a single-phase unit, but recently it has been required for three-phase distribution. A voltage compensator is to be provided at the power station. The switchboard connections are practically as indicated in the diagram, Fig. 539 (a). The connections for the compensator and its voltmeter are as shown in Fig. 539 (b). With single-phase operation, but two series transformers were required in connection with the three ammeters. The question now arises as to the proper method of connecting the compensator on the three phases, using the same two series transformers for the compensator and the ammeters. Please give correct arrangement of circuits. C. M. G.

Ordinarily, two series transformers may be connected as in Fig. 539 (a) so that the current

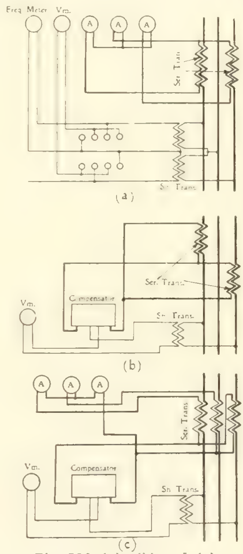


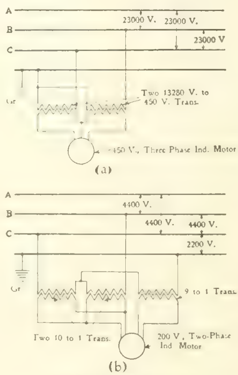
Fig. 539 (a), (b) and (c)

from each one is proportional to the current in one line, and the resultant of the two transformers is proportional to the current in the third line. However, this method of connection is not suitable for use with a voltage compensator because each line of the compensator

should connect to the incoming end of one transformer and to the outgoing end of the other, as in Fig. 539 (b), whereas the common line from the two transformers to the ammeters must connect to corresponding ends of both transformers. A method of connecting by means of three transformers is shown in Fig. 539 (c). Two transformers are used with the ammeters, and two with the compensator, the left hand transformer being used for both compensator and ammeters. H. B. W.

540—Special Grounded Polyphase Transformer Connections — The two transformer connections indicated in Figs. 540 (a) and (b) are in use on a local power system. They operate satisfactorily, but I would like some further information regarding them. Fig. 540 (a) represents a three-phase—four wire 23 000 volt system connected in Y with the middle point grounded, and supplying power to three-phase motors at 450 volts. *a*—Does this give a perfectly balanced three-phase system? Will you kindly explain: *b*—The name of this connection? *c*—The secondary voltage relations? *d*—What percent of full load can the motors carry? *e*—The currents in the various windings of the motor? Fig. 540 (b) represents two-phase motors operated from a three-phase—four-wire 4 400 volt line with middle point grounded. *f*—Does this give a perfectly balanced two-phase system? *g*—What are the voltages across the motor terminals? *h*—What are the currents in the various motor windings? *i*—What percent of full load can the motors carry? F. T. P.

a—The secondary voltages and currents are balanced in three-phase relation. The line current in the neutral wire is equal to $\sqrt{3}$ times the current in line *B* or *C*. The connection is the same as the ordinary star-delta connection with one transformer of the group cut out. (See No. 96, July, 1908). It should be noted that the voltage to neutral on a three-phase, star-connected system is not one-half line voltage as given in your diagrams, but approximately 58 percent of line voltage. *b*—This connection is ordinarily called open delta or "V". *c*—The secondary voltages of all the phases are equal and form a closed triangle. *d*—The k.v.a. on the transformers is always 15 percent greater than the k.v.a. of the motors. Hence, if both have the same rating, the motors can carry but 86.6 percent of the rating of the transformers without overloading the latter. *e*—The currents in the motors are normal, being exactly the same as



Figs. 540 (a) and (b)

if operating from the ordinary delta-delta transformer connection. *f*—The two phases are 90 degrees apart, but badly unbalanced as to currents and voltages. *g*—With ratios of transformation and line voltages as given, the voltages at the terminals of the motor are 220 volts from the 10 to 1 transformer, and 140 volts from the 9 to 1 transformer. *h* and *i*—With such wide difference in voltages, the phase at the higher voltage will carry much more than its share of the load. The exact current distribution and load which the motor can safely carry depends on the in-

dividual motor and cannot be determined unless its design is known. By using two 9 to 1 transformers, connected in series with line *A*, with the secondaries in parallel, a very nearly balanced two-phase source of power for the motor can be obtained, which will give far better results and enable it to carry a load practically equal to its full rating.

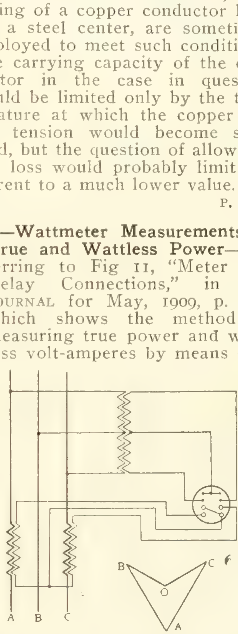
E. C. S. & A. M. D.

541—Relation of Strain to Sag in Over-Head Conductors—A river is crossed by a transmission line by means of towers separated by a 900 ft. span. The conductor which is of No. 0 copper is supported by a steel wire. Was it necessary to use a steel messenger wire to avoid excessive strain which would result in the copper conductor if it were used alone? Would you suggest hanging it in catenary form? What would be a safe carrying capacity in amperes? J. K.

The tension in a conductor carried between two supports of the same height is proportional to the square of the span and inversely proportional to the deflection or sag. This may be expressed as a formula thus: For copper, $T = 0.486 \times S^2 \div d$, in which *T* equals strain in lbs. per sq. in. in wire; *S* equals span in feet; and *d* equals deflection in feet. For aluminum, the constant becomes 0.147. Having obtained the value of *T* for a given case, the actual pull in lbs. per sq. in. may be derived by multiplying this value by the area of cross-section of the conductor expressed in equivalent square inches. Thus, in the present case the strain in lbs. per sq. in. would equal 0.486×900^2 divided by the maximum allowable deflection in feet, the latter being determined by the clearance required for the conductors above the river level. Assuming that the towers are of sufficient height above the water level to allow of a sag of 50 feet, the strain would then be 7870 lbs. per sq. in., which with a No. 0 wire would represent a tension of 660 lbs. per sq. in. Without all data being furnished it cannot be determined whether or not the steel messenger was required to avoid excessive tension in the copper conductor. It may be that the conditions were such that the allowable sag was so limited as to necessarily involve a high tension in the wire, thus requiring a steel wire. It should be noted that the allowable sag is also limited by the possibility of the wires swinging together, especially with long spans. Bi-metallic conductors, consisting of a copper conductor having a steel center, are sometimes employed to meet such conditions. The carrying capacity of the conductor in the case in question would be limited only by the temperature at which the copper under tension would become softened, but the question of allowable line loss would probably limit the current to a much lower value.

P. M. L.

542—Wattmeter Measurements of True and Wattless Power—Referring to Fig 11, "Meter and Relay Connections," in the Journal for May, 1909, p. 306, which shows the method of measuring true power and wattless volt-amperes by means of a



Figs. 542 (a) and (b)—Wrong method of connection for measurement of wattless volt-amperes

single polyphase meter and a four-pole, double-throw switch, please explain why shunt transformers with 50 and 86.6 percent taps are specified for obtaining the wattless volt-amperes of the power circuit. Consider the regular vector diagram for three-

phase measurements as shown in Fig. 542 (a); combining voltage *AB* with the current in *BO* gives a measurement of true power and combining voltage *AB* with current *CO* or voltage *AC* with current *BO* would give a measure of wattless volt-amperes. If the transformers are connected in star the currents will have a phase difference of 120 degrees and the voltages will have a phase difference of 60 degrees, the same as though the transformers were connected in V. Then voltage *AB* is 90 degrees from current *CO* and likewise voltage *AC* is 90 degrees from current *BO*. As the conditions are represented in Fig. 11 (b) of Mr. Brown's article, the voltages are 120 degrees apart and the currents likewise, they being combined at 120 degrees. I do not understand why it is necessary to shift the voltage 30 degrees (by means of 86.6 percent taps) in order to obtain the correct measurement. Unless there is some very serious objection to measuring the wattless volt-amperes as I have outlined, it seems to me it would be much simpler and would necessitate no special transformers.

S. W.

If a method such as that proposed above is used for measuring the wattless component, the value of the voltage applied to the meter should be the same as from any one line to neutral and not the voltage between lines. Also, three series transformers would be required, one on each line, in order to measure the total volt-amperes in all three lines; with only two transformers the power measured would be that of two lines. The fallacy of your argument may be illustrated numerically as follows: Assume a current of five amperes on each line, and a voltage between lines of 100 volts. At 100 percent power-factor the true watts, which a wattmeter should indicate, will be the same as the volt-amperes—namely, $1.732 \times 5 \times 100 = 866$ watts. It is evident that a wattmeter with the usual connections will read this, because the current in each current winding is 30 degrees out of phase (cos 30 degrees $= .866$) with the corresponding voltage, and the watts on each phase will be $0.866 \times 5 \times 100 = 433$ watts. At zero power-factor, with the same current and voltage, the wattless-component meter should indicate the same as above, but the current will be exactly in phase with the voltage, and the meter will indicate for each phase, 5×100 apparent watts, or for both phases 1 000 apparent watts, instead of 866. Furthermore, with unbalanced loads your connections would give readings inconsistent with themselves. For example, if this current is flowing only in *A*, and lagging by an angle of 90 degrees, and it returns through *B*, the indication on the wattless component meter due to this current will be 5×100 apparent watts. But if it flows through *C* and returns through *A*, Fig. 542 (b), the meter will indicate differently because the current will flow through both sides of the meter. The indications are inconsistent, because in reality the wattless component is the same in the two cases. In the article referred to the right phase relation is established by merely shifting the voltage through an angle of 90 degrees from its position for measuring true watts, so that instead of indicating the product of volts and amperes in phase with each other, the meter indicates the product of volts and amperes in quadrature (i.e., 90 degrees out of phase) with each other. The 50 percent and 86.6 percent points on the transformers are for the purpose of making the voltage of the same value in the two cases. There was an omission of two lines of the text following the first line on page 305 of the article, (as noted on page 384 of the June, 1909, issue), as follows: "circuit 90 degrees, the wattmeters have been made to indicate wattless volt amperes instead of true watts. This is accomplished on the". This obviously has an important bearing on the explanation of the method.

H. W. B.

THE ELECTRIC JOURNAL

Vol. VIII MAY, 1911 No. 5

Development of the Low-Pressure Turbine

Whenever we learn of a remarkably economical steam power plant, we are usually more eager to inform ourselves about the details of the particular mechanisms employed, than we are to study the broad underlying engineering principles that are involved. Low-pressure turbines have been installed in connection with reciprocating engines in so many instances during the last few years, and the economic results have been in general so gratifying, that we are apt to think that the low-pressure turbine is a wonderful new development that in some mysterious way makes these remarkable economies possible.

The low-pressure turbine is not new; it differs from the turbine using steam of 175 or 200 pounds initial pressure, only in that there is less of it. Fifteen years ago the steam ends of all turbogenerator units of 750 kilowatt capacity and over, were made up of a high-pressure and a low-pressure turbine coupled together. The former expanded the steam from boiler pressure to about atmospheric pressure, exhausting into a receiver; from the reciever the steam passed to the low-pressure turbine where is was expanded to the pressure existing in the condenser. At that time, no one regarded the low-pressure turbine as being remarkable or unusual; in fact, it looked just as logical as the low-pressure cylinder on a compound reciprocating engine.

About ten years ago a turbine of 1 500 kilowatt capacity was installed by the Hartford Electric Company, which was not only record breaking in point of size, but also in that the complete expansion of the steam was carried out in a single cylinder. This looked like a very reckless bit of engineering at the time, but the troubles confidently predicted for it never materialized. As a result, the low-pressure turbine which was previously regarded as an expensive but necessary evil, became unfashionable and was practically forgotten, while single-cylinder turbines increased in size to upward of 10 000 kilowatts, with no apparent limit in sight.

It has been many years since any intelligent engineer would have expressed surprise at a suggestion to couple a low-pressure reciprocating engine to an existing engine that was overloaded or that was exhausting to the atmosphere. It has not always been considered essential that the high-pressure and low-pressure engines should be mechanically connected. In many blowing engine installations for blast furnaces and steel works, it has been customary to operate low-pressure condensing engines with the exhaust steam from independent high-pressure engines. Nearly fifteen years ago Professor W. T. Magruder showed the writer a combination of this sort in the Mechanical Laboratory of the Ohio State University, which was used for research work in connection with the study of the proper ratio of cylinder volumes for compound engines. By varying the relative speeds of the two engines, any desired ratio of cylinder volume per unit of time could readily be maintained.

In our present low-pressure turbine practice, we are therefore reviving an almost forgotten mechanical device which we ought to have remembered as being peculiarly well adapted for reducing our most thoroughly established thermodynamic theories to practice. The most efficient part of a steam turbine is the low-pressure end, i. e., that part in which the range of pressure is from that of the atmosphere down to that of the condenser. It makes no difference to that part of the turbine whether it receives its steam from a high-pressure section just preceding it, or from a reciprocating engine or from any other source whatsoever.

We produce the low-pressure turbine therefore by the simple process of eliminating the section in which the steam would ordinarily be expanded from boiler pressure to atmospheric pressure. We have always recognized the economic possibilities of utilizing the utmost degree of expansion that the lowest condenser pressure will allow, but the mechanical features of the reciprocating engine have compelled us to stop far short of the desired limit. At the lower pressures, the volume of the steam would call for cylinders of prohibitive dimensions; the engine parts would be so massive that the thermodynamic gain would be obliterated by mechanical friction, and no valves and ports could be made large enough to prevent wire drawing and allow the minimum condenser pressure to be realized in the cylinder.

The turbine, on the other hand, can, without exceeding moderate dimensions, handle enormous volumes of steam; the mechanical friction is almost negligible as compared with that of a re-

ciprocating engine, and the exhaust port is larger than the steam passages, so that the full value of the condenser pressure is available.

The alternating-current generator furnished the opportunity for the rapid and enormous development of the steam turbine, which lay in a dormant state for years, because there was previously no field for a prime mover, the speed of which is inherently so high. Similarly, alternating-current generators in parallel or driving synchronous motors, make a beautifully convenient and effective arrangement for coupling a reciprocating engine to a turbine in such a way that the speed of the latter is no hindrance to utilizing it as the most efficient low-pressure cylinder that it is possible to devise for a double or triple compound engine.

The writer ventures to suggest that Mr. Dreyfus' interesting article on "Various Phases of Low-Pressure Turbine Work," appearing in this issue of the JOURNAL, should not be looked upon as a mere statement of what a low-pressure turbine can do of itself, but that it should be considered rather as an exposition of the economic advantages of realizing as nearly as may be, the possibilities indicated by thermodynamic theory. The low-pressure turbine is responsible for the results only in so far as it is the mechanical device that brings practice most nearly into contact with theory.

H. E. LONGWELL

Transformers and Transmission Apparatus

Developments in transformers and transmission apparatus during the past few years have very considerably changed the attitude of electrical men toward the problems encountered in transmission work. Only one or two plants were operating at as high as 50 000 volts when Mr. Peck wrote the original of the article which appears in revised form under his name in this issue of the JOURNAL. The question of transformer insulation, of protecting from surges within the system and difficulties from lightning, were all matters which were just in the beginning of theoretical study on the one hand and practical experience on the other. Mr. Peck outlines various fundamental conditions respecting the practical results which might follow the connection of transformers in various ways, showing in particular certain abnormal conditions which might follow an accident in a system which would operate satisfactorily under normal conditions. The article, however, has lost much of its immediate importance to the operating engineer for the reason that many of the possible difficulties pointed

out are not liable to occur, as proper precautions are now taken in the design of the transformer and of the system of which it forms a part. In other words, the general problem is no longer an open one, but common practice has developed along the lines of safety and reliability.

One of the important factors in bringing about the new conditions is the remarkable reliability of the modern transformer in its freedom from breakdown, even though operating under the most exacting conditions and often with but little or no auxiliary lightning protection. Furthermore, it has become customary in three-phase transmission to regard a bank of three transformers as a unit. Consequently, provision is not made by fuses or circuit breakers for automatically cutting out an individual transformer in case of accident, thereby aiming to retain the remaining transformers in service. Hence, fuses and circuit breakers are not placed inside of a delta connection. Practice has settled on the use of connections which give a stable neutral point, either through the use of the delta or combinations of delta and star connections, or by connecting the neutral point of the generator to the neutral point of the step-up transformers, where this connection is admissible. Some of these connections raise questions as to triple harmonics and the resulting flow of unbalanced currents in the closed delta. These matters have been discussed in various recent papers.

In general, the modern operation of transformers and transmission work along present standard lines can hardly be considered as subject to many of the serious voltage distortions referred to in the article by Mr. Peck. His analysis of the problem, however, is exceedingly interesting as indicating the basis of present practice and pointing out the difficulties into which one is apt to fall under the particular conditions cited. The article, as above indicated, is of particular interest in showing the substantial advance which has been made in the theory and practice of transmission in the past few years, due largely to the work of the Transmission Committee of the American Institute of Electrical Engineers, to which Mr. Peck's paper was one of the early contributions. K. C. Randall

Water Powers and Government Control

How to secure government action which will remove the conditions which retard the development of our water powers was the fundamental question which led to the conference held last month under the auspices of the Transmission Section of the National Electric Light Association. At the outset is was seen that there was no necessity for protesting against self-sufficiency on the part of government officials nor their unwillingness to listen to the views of those commercially interested in power transmission, as the new Secretary of the Interior, Walter L. Fisher, accepted the invitation to be present and attended the conference.

After the opening remarks of the chairman of the meeting, the Secretary stated that he fully appreciated the importance of the questions raised and was ready to hear all points of view. He dissented from the assertion that the government had established a definite policy. He said that the position of the government was negative as the object is to prevent progress along improper lines and to call a halt until a definite, positive course could be determined. He believed that there would be no fundamental difficulty in adjusting the relations of the National and State Governments, and in his remarks at the close of the conference he said that a substantial beginning of a much needed enlightenment and education of the people at large upon the facts and questions at issue regarding the matter of water power development, had been made during the present conference.

The principal addresses pointed out in detail the importance of the utilization of our water powers, and the difficulties in making developments under the present government relations. In order to secure rights to develop the water power itself and to run transmission lines across Government lands it is sometimes necessary to secure permits from three of four departments of the Government, and even then the rights to the power itself may be revocable at the discretion of the Government. The difficulty in interesting capital under these and other unsatisfactory conditions was presented.

It was interesting to find that there was an almost unanimous sentiment in favor of continued official supervision of the operation of power transmission companies which were essentially public service corporations. It was held that questions as to the duration of water rights or franchises and the question of taxation or

royalties to be paid to the Government might easily be determined if the matter of rates of charge and the relations between the power companies and the public were left to the supervision of the States, presumably through public service commissions.

This recognizes water power development in its future position as an important source of electric power for all classes of service upon which the transportation, the industries and the domestic life of a community will be as dependent upon a general power supply as it is at present upon a public water supply. It also recognizes that the policy which has been developed through three-quarters of a century of railroad operation in which the railroad has come to be regarded as a quasi-public corporation and subject to regulation by the State legislature is also applicable to power companies. Just as the State now protects the public by fixing railroad rates, and as it protects the railroad by insuring that its rates shall be high enough to provide an adequate income, and as it has power to prevent the waste of capital in the construction of unnecessary, competing lines, and to supervise the issuing of new securities, thus protecting investors, so also may the function of the State be extended to the proper development and operation of our water powers to the common benefit of all concerned.

Almost the whole temper of the meeting was constructive. The engineering development of power transmission has been so rapid that public policy and laws have not kept pace with the new conditions and new problems. It is not to be expected that the policies and laws of a dozen years ago will serve present conditions any more than it would be reasonable to condemn the electrical apparatus and engineering methods of a dozen years ago, because they are inadequate for the requirements of great transmission systems of the present, and the future. We are simply encountering a normal problem in evolution and a good start has been made in getting at the true conditions which underlie the new economic and legal problems which modern power transmission has brought about. As the Secretary said at the close of the conference, it would be well to start with a clean slate, to forget past mistakes on all sides, and to join in the formation of a constructive policy which may be fair to all concerned.

CHAS. F. SCOTT

An Electric Supervisor

We are familiar with electrical apparatus for the performance of ordinary mechanical functions, but we are not so well accustomed to its use as a substitute for human functions. Yet Mr. Walton, in the opening paragraph of his article in this issue of the Journal, shows in a striking way how an electrical instrument is a superior overseer and supervisor of factory operations. It has unlimited patience and nervous endurance and a peculiar acuteness of observation and impartiality in its records. In many ways it performs its service better than could any human agency, but it also goes further and observes happenings which would ordinarily be overlooked or which are impossible for a man to see, and it records them in a definite, reliable and quantitative way.

A description of the use of graphic meters in textile mills is merely a specific illustration of some of the uses to which this instrument may be applied, not only as a constant overseer and recorder of various occurrences, but also as a means of analysis, by which the precise cause of inefficient operations can be determined, and as a means of detecting faults which would otherwise be overlooked, and of stimulating the same maximum of effort which would result from the constant presence and personal supervision of overseers in each department.

In the effort for increased efficiency through improved equipment and scientific management, electrical apparatus is available for the human as well as the mechanical functions.

GRAPHIC METERS IN TEXTILE MILLS

ALBERT WALTON

UNREMITTING attention is impossible in human assistants. Nerves wear out, interest flags, monotony stupefies the mind, nature demands relief and rest. But while man's ability to keep his faculties concentrated is limited by his physical and nervous endurance, he has been able to devise instruments which possess some of the qualities which he lacks, whose attention will not flag however long the hours, which will observe each happening that occurs under their supervision and will keep accurate records of all these incidents in their order.

An instrument of this kind is the graphic meter, which consists of a fountain pen with a month's supply of ink, a self-winding clock, a few coils and contacts, all in a glass box hung on the wall or switchboard. It is a comparatively simple instrument, but it can deliver some remarkable information if given an opportunity. One form of meter registers all the changes of voltage that occur on an electric circuit, another records current values, another power, a fourth, speeds. Their uses are manifold and their returns interesting, instructive and enlightening. With their aid secrets are revealed and information secured the very existence of which may have been unknown before.

In a textile mill a graphic meter installed on the switchboard or in the overseer's office will show how quickly the entire loom room is put into operation. It will show when the spinning frames are started and when they are doffed. If the pickers seem to be having difficulty in supplying the necessary number of laps to the cards and the men assert that they can do no better, it is easy to check up and see if they are getting the laps off quickly and keeping the machines properly fed.

Nor is it necessary to have a separate meter for each room or each machine. One meter can be arranged so that it can be readily connected to any set of wires in the mill. By pulling out one set of spring plugs and pushing in another set the meter can be transferred from one set of feeders to any other. Thus a record of the morning session can be taken on a 100 horse-power motor in the spinning room and the same meter switched over on to a 75 horse-power motor in the weave-shed for the afternoon by shifting plugs

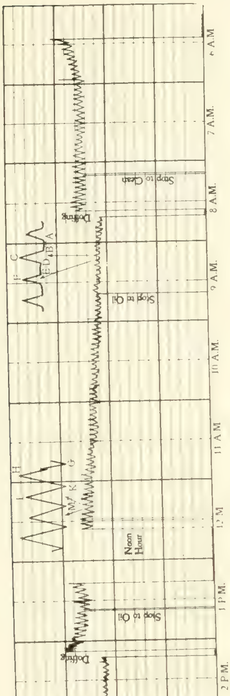


FIG. 1—GRAPHIC METER RECORD FROM FIVE HP INDUCTION MOTOR, DRIVING WHITIN 256 SPINDLE SPINNING FRAME, SPINNING NO. 26 WARP. SPINDLE SPEED, 9 200 R.P.M., RING 1.75 INCHES DIAMETER

The section of the curve at the top have been enlarged four times to show more clearly the shape of the peak.

at the switchboard. No one in the rooms where the motors are located will be able to tell whether the meter is in his circuit or some other and thus, while it is recording the work of only one feeder line at a time, it has the effect, so far as the help is concerned, of watching the entire mill all the time.

Many of these meters are in use in the mills of New England where they are considered as essential a part of the mill equipment as the less reliable, though necessary, night watchman. One mill was taking power for its lights from the local central station and just when they needed it most the light seemed weakest. Yet many of their lamps burned out. This led to an inconclusive discussion as to the cause of the trouble, which was finally settled with great expedition by a recording voltmeter. A day's record showed excessive fluctuations in voltage, and by recording the exact time of their appearance enabled the central station to locate the difficulty and eradicate it.

A large Massachusetts cotton mill distributes current from its central power house over eleven different circuits to as many groups of motors in the mills. By inserting a small plug in its proper receptacle a curve-drawing meter can be connected to any one of these circuits. No overseer in the mill knows on a given day

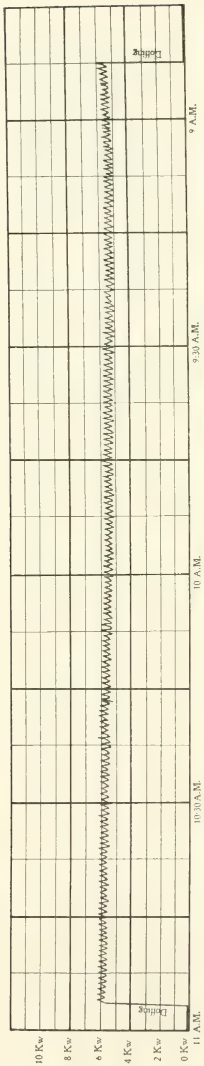


FIG. 2—CHARACTERISTIC DOFF TO DOFF RUN ON 200 SPINDLE WORSTED FRAME, SPINNING NO. 40 WARP; SPINDLE SPEED 7 000 R.P.M., DRAFT 5.6, TWIST 14.3, 70 GRAIN ROVING, FOUR-INCH TRAVERSE

whether his power record is being taken or not, but he knows that if it is being taken he cannot shut down a spinning frame without the act being recorded down in the engine-room. In this way the management is certain that "cleaning up time" will not begin before it is due; that the weavers will not be changing their clothes at either end of the session when they should be watching warp and filling; that several spinning frames are not shut down to let the spinners catch up when the yarn runs badly, due to their own neglect and inattention.

Every agent is accustomed to seeing new life put into the work, the instant he appears in the doorway. Weavers get up from their restful stools, doffer boys quit chasing each other about, spinners stop their little chats and busily piece up ends. The agent knows they go back to it when he leaves, yet he cannot be in all the rooms at once nor even in the mill all the time. If he could keep up this maximum of effort all the time, if he could know where the falling off comes in and when and why it occurs he could demand results of his overseers. Otherwise he is in their hands and must rely on their opinion as to how many pounds of product he can expect to take off in a week. Even an honest and experienced overseer is human, and is liable to err on the low side to make a good showing. An analysis of a series of curves from a graphic meter will give incontrovertible facts that will surprise the overseer himself.

In addition to this general supervisory function, the meter is of great value where individual drive is used, as it enables one to ascertain the effect of various factors in the machine and its method of operation. By recording all the changes of power through a complete cycle of operation some valuable information may be obtained. For example, Fig. 1 is a curve taken from a cotton spinning frame, while Fig. 2 is a similar curve from a worsted spinning frame.

For an explanation of the definite cycle of operations shown in these curves, a brief description of the spinning operation is necessary. Strands of coarse twisted yarn called "roving" are led from the bobbins on which they have previously been wound, through two pairs of slowly revolving rollers and then through another similar pair, revolving several times as fast. The strands from the roving bobbins are thus combined into one which is drawn out by the third pair of rollers into a fine and practically untwisted thread, and must be twisted before it will be useful.

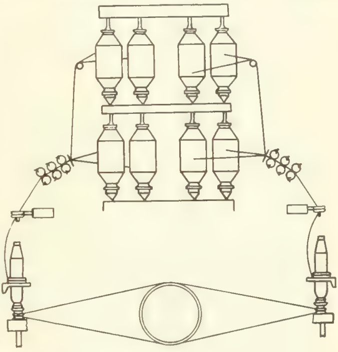


FIG. 3—SCHEMATIC DIAGRAM OF RING SPINNING FRAME

The twisting of the yarn is accomplished by revolving the bobbins on which it is wound at from 5 000 to 12 000 r.p.m. The spindle and bobbin are centrally located in a steel ring which is in turn mounted upon a rail. Mounted upon this ring and free to revolve around it is a small traveler. The yarn, leaving the rolls, passes through a guide eye directly over the spindle and through the traveler to the bobbin, as shown in Figs. 3 and 4. Were the traveler fixed in position on the rings, the yarn would tend to be wound on the bobbin at a tremendous rate without being twisted, with the result that it would be broken instantly. Were the traveler to turn at the same speed in revolutions per minute as the bobbin, the yarn would be twisted, but would not be wound on the bobbin. As a matter of fact, the traveler is carried around the ring at very nearly the speed of rotation of the spindle, but friction causes it to lag

back sufficiently to wind the yarn as fast as it comes from the rolls, and to keep it fairly taut between the rolls and the bobbin. The ring rail is raised and lowered by a cam mechanism at a suitable rate to cause the yarn to be wound in even layers.

The history of the day's run, as recorded by the curve, Fig. 1, shows that the frame was started with the bobbins partly filled. The power fell off rapidly for the first half hour, and then gradually rose as the bobbins became more nearly full and required more power. The frames were doffed, i. e., the full bobbins were removed and replaced by empty ones, at a few minutes past eight, the operation requiring about four minutes. The motor then ran until the noon hour with only two momentary stops for oiling. The afternoon run was a repetition of the forenoon.

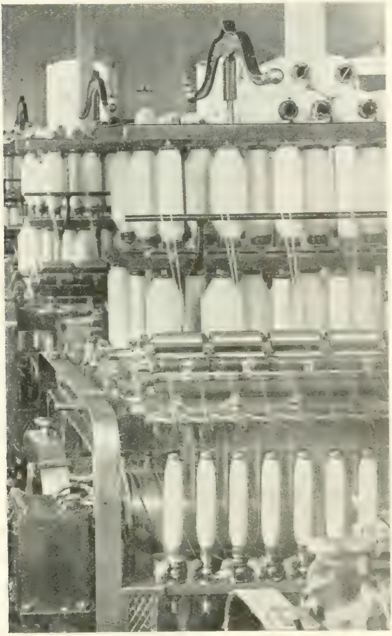


FIG. 4—RING SPINNING FRAME IN OPERATION
The ring rail was moving up and down over the bobbins while this photograph was taken, and hence does not show.

Closer examination of the curve reveals that about twenty percent more power is required at the end of a run than at the beginning, increasing at a fairly uniform rate. This is a characteristic of all ring spinning frames, and has been proven experimentally to be due almost wholly to the fanning action caused by the rough surface of the yarn, and its constantly increasing peripheral speed as more cotton is wound on the bobbin. That the added weight

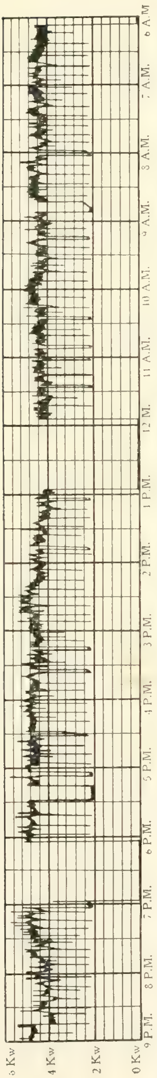


FIG. 5—RECORD FROM 7.5 HP INDUCTION MOTOR DRIVING KITSON SINGLE BEATER INTERMEDIATE PICKER. BEATER SPEED, 1,470. COTTON, ONE INCH STAPLE. 47.0 YARD LAP WEIGHING 50.6 POUNDS NET, OR 1.05 POUNDS PER YARD PRODUCED IN EIGHT MINUTES

has little to do with the extra power is proven by the fact that the empty bobbins require practically the same power as the bare spindles, although the bobbins weigh about half as much empty as full.

Every traverse of the ring rail is indicated by the regularly occurring peaks, and observations at the time of taking the curve show that the power increases as the ring rail descends. The shape of the peaks also changes as the bobbins become filled. In the exaggerated section shown at the top of the curve, it may be seen more clearly that the peaks are higher and practically continuous with the full bobbin, while with the empty bobbins they are smaller and are joined by short lines of minimum power. This increased power consumption occurs at the same time as the ballooning or flying out of the yarn due to centrifugal action. With the empty bobbin the tension is great enough to prevent this action while the ring and traveler are close to the guide eye, and the load is practically constant, as indicated by *AB*, Fig. 1. Ballooning starts when the ring rail has passed somewhat beyond the mid position and the power *BC* to drive the yarn through the air increases, until the ballooning reaches its maximum at the bottom of the rail travel. *CD* shows the decrease of power required as the length of the revolving yarn decreased, until at *D* the straight line form was again assumed. With the full bobbin the tension on the yarn is much less, and ballooning occurs throughout the entire range of rail travel, as shown by the curve *GHKLM*, while the greater extent of the balloon requires a greater amount of power.

The number of layers of yarn on the bobbins may be counted by the number of peaks. In the morning run 78 lifts of the

rail are recorded, while in the afternoon run but 75 lifts are shown. In the longer run, just before the removal of the bobbins, the yarn began to rub against the ring and traveler, causing the curve to be very ragged and irregular. The duration of the doffing time and the exact instant the frame is shut down is marked and the overseer must answer the "why" if this is found to be of too frequent occurrence or too long duration.

Fig. 5 is a curve from a picker. This machine forms a step in the process of transforming the baled and dirty cotton into rolls of clean, fleecy material of uniform texture and thickness. In order to secure uniformity of final product, the raw material throughout the entire process is intermingled as much as possible. The raw cotton is mixed and beaten in the openers and breakers to a light, fluffy mass, most of the sand and dirt being removed at the same time by air suction. The cotton leaves the breaker in the form of

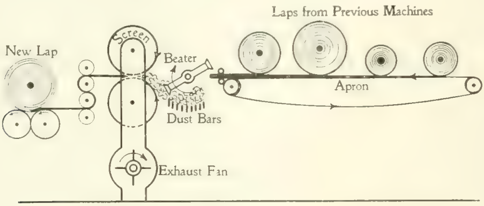


FIG. 6—SCHEMATIC DIAGRAM OF INTERMEDIATE PICKER*

laps of approximately uniform thickness. As indicated in Fig. 6, four of these laps are fed simultaneously to the intermediate pickers. This quadruple sheet is beaten apart, and again spread out and wound up as a cleaner and more uniform lap. This process is again repeated in the finisher pickers, the lap formed here being about 40 inches wide and 16 inches in diameter, containing about 50 yards of loosely laid cotton, about one-half inch thick, and weighing about 45 pounds.

The desirability of producing laps of uniform weight has made necessary the provision of an automatic device for stopping the feed after a certain number of revolutions of the roll on which the lap is formed. As shown by the curve, Fig. 5, this occurs about every eight minutes. Examination of this curve will show when the attendant failed to place a lap on the apron in time and thus

*See the JOURNAL for March, 1911, Fig. 3, p. 239, for illustration of this machine.

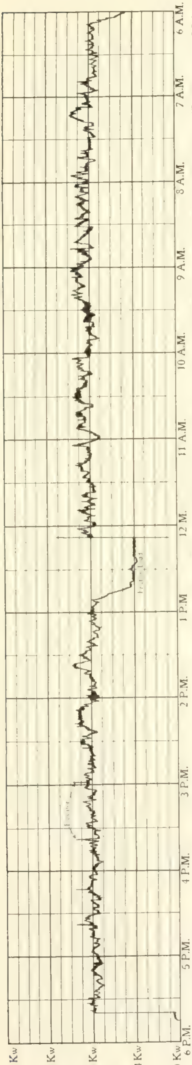


FIG. 7—RECORD FROM 100 HP INDUCTION MOTOR DRIVING WEAVING, SLASHING, WINDING, BEAMING, WARPING AND CLOTH ROOM MACHINERY, AND ELEVATOR. SLASHER ROOM RUNNING DURING NOON HOUR. Note length of time required to get looms started.

permitted three laps to be fed instead of four, thus affecting the weight of the yarn possibly for a thousand spindles for an hour. The evener tends to correct this omission by speeding up the apron, but the less resistance to the beater blades is evident. The curve also shows whether he started another lap immediately when the stop motion tripped or whether he allowed the machine to run idle for a time. In taking off this record the next day after it was made the writer asked the boss carder what the trouble had been between 5:00 and 5:30 P.M., but he knew of no difficulty and was inclined to lay it to the meter. On being pressed to investigate, he found that a loose evener belt had become lint-covered and slipped badly for three or four laps, finally necessitating shutting down the picker to take it up. The chances are good that many light-weight laps were taken to the cards in the meantime without his knowledge, for an inspection of records for two or three days preceding showed the same trouble, though in a lesser degree. The overseer should have such a meter in his office from which two wires could run to each picker and enable him to check up all such occurrences immediately after they happened and to prevent their recurrence.

To the ingenious mill man with an analytical mind the foregoing will serve only as bare suggestions. Immediately he will think of many other uses for such an able assistant, any one of which will insure very liberal returns on the small outlay required, for there are many things he has long wished he could know about his mill, but which, without some such device as the graphic electric meter, he cannot possibly hope to discover.

CONSERVATION OF WATER POWERS

AND THEIR DEVELOPMENT FOR THE PUBLIC GOOD

SIDNEY Z. MITCHELL

[A public conference on "Water Powers and their Governmental Control," was held on April 8th, under the auspices of the Power Transmission Section of the National Electric Light Association at the Engineering Societies' Building, New York City. The opening remarks of the chairman and the address of the first speaker are here given in condensed form]:

OPENING REMARKS OF CHAIRMAN H. L. DOHERTY.

ACCORDING to the last census there is 37 000 000 horse-power available in the United States in water power which can be developed at a cost which compares favorably with steam. Of this amount about 1 600 000 horse-power has already been electrically developed and approximately 1 900 000 horse-power has been developed for industrial purposes through means other than electrical, leaving approximately 33 500 000 horse-power still available for development and use for this and future generations. In all probability these figures will prove far too low when a more careful investigation has been made.

To develop even the smaller amount of power named above would require to exceed $7 000 000 000. It is interesting to note that the undeveloped water-powers of this country exceed the total amount of power now generated by all known means. We are to-day using annually in excess of $200 000 000 of fuel that might be saved by the development of our water-powers.

After a careful study of fields of possible useful work it was the unanimous opinion of the officers of this Section that the greatest obstacle to the development of water-powers at the present time was the attitude of our national and state governments. The policies of our governments have largely been dictated by men inexperienced in this line of work. Obstacles have been placed on the development of water-powers which are burdensome to the degree of being prohibitive, and which are of no benefit to the government or to the public.

It has been suggested that the present controversy may be partially due to an unrecognized difference in the fundamental premises which have been unconsciously assumed without careful analysis, and by this I mean that one class, taught by the more recent and impractical school, assumes that the public lands are the absolute property of the government, intended only to enrich the treasury of the government without regard to other considerations, while the older and more practical school assumes that these lands are held in the nature of a trust and should be used for the settlement and development of the territory where they are situated, and thus contribute to the development of the entire country. The latter school is in accord with the precedents which actuated the government through many decades, and while precedent alone should not govern in matters of this sort, there is a consideration which precedent in this case has injected, and which is of prime national importance, and I mean by this that a question of what constitutes fairness and justice has been injected into this problem that cannot be neglected.

It is a well-known fact that is no longer questioned in law, that every quasi-public corporation is subject to the regulation of its rates, either by the state legislature or to some other body to whom the legislature has delegated this power, which otherwise inherently vests in the legislature. If we keep in mind this fact it can be made plain that every objectionable restriction and obstacle, placed by the government on the development of water-powers, is unnecessary if not absurd.

THE real conservation of water power means its use. The only methods of producing power are through the consumption of coal, oil, gas, wood and other fuels which exist in limited quantities and cannot be replaced, and which are being consumed and exhausted at a rapid rate; and through the use of water powers. It has been estimated that there are now being used annually in the United States more than four hundred and eighty million tons of coal, worth, on an average, $2 per ton, or a total of about $960 000 000 annually, to say nothing of the annual consumption, in addition, of millions of dollars' worth of oil, natural gas and wood.

By the use of water power, this frightful consumption of fuels can be minimized and in many cases wholly obviated. I say frankly to this gathering of practical business men that I think the Government officials who have awakened the American people to the need of conserving the exhaustible natural resources have performed a great public service. No one can state too strongly for me the evils of the wanton and unnecessary consumption and exhaustion of our growing timber, our coal and our other fuel supplies.

While we all agree upon the necessity of conservation, we are not able to practice it. Take this very association, for example. We now have over seven thousand members representing, approximately, six thousand cities and towns in the United States, and the properties represented by the members here are supplying at least sixty millions of our people with electricity for running trolley cars and for manufacturing, lighting, cooking and irrigation. I venture to state that the companies represented here are exhausting this country's non-replaceable fuel supply to the value of over thirty-five millions of dollars annually; and the sad thing about it is that they are compelled to do it.

Thousands of engineers, promoters and economists are impressed with the advantages of water powers, and are daily trying to raise the cash for their development; yet progress in this direction is exceedingly slow. I am going to mention some of the reasons for such slowness. The public at large has an idea that since water naturally runs down hill water power must cost practically nothing. The average investor knows through his own experience, or his friends', that the wonderful profits of the water power business exist only in the dreams of the promoters or in the minds of sensational magazine writers. The careful investor will point to the many dozens of colossal fortunes made in real estate speculation, in the gro-

cery and hardware business, and in department stores, in manufacturing and in banking, etc., and will ask the promoter to point out a few of the colossal fortunes made in the water power business. If the water power is on a so-called navigable stream, or in any way touches Government land—and this means nearly all the largest and best undeveloped water powers of to-day—the investor will call attention to the uncertainties and onerous restrictions involved in the development and operations of such powers. In practically 999 cases out of 1 000 the enterprising promoter of local industries returns to his home town discouraged and defeated by the present state of our laws, and the water power continues to run to waste as in the days of Columbus.

That I may not be misunderstood, let me restate my position to this point:—

1—The true way to conserve our now idle water powers is to use them. The true way to conserve our limited fuel supplies is not to use them—but to use water power instead.

2—The absolute necessity for the conservation of those exhaustible natural resources not subject to replacement is apparent to us all.

3—Yet the majority of the men, women and children in the United States are engaged at present in the destruction of such exhaustible natural resources and we are compelled to destroy them by the existence of conditions over which we seem to have no control.

If this be a sound statement of the case, how can we better the conditions? It is with a full appreciation of the complexity of the subject, growing out of a quarter of a century of practical work, that I make some suggestions; not in any attitude of opposition to the Government or to any of its officers, but with that friendly spirit of helpfulness and co-operation which it is hoped will aid in the correct solution of the problem before us.

The distinction between water powers operated for private purposes and those operated for public purposes seems to me so logical and so important that it must be recognized in future legislation. Too much emphasis cannot be laid upon the radical difference between the pulp mill or factory type of water power used entirely in a private business and the water power used for the generation and distribution of light, heat and power. The latter is the servant of a widely-scattered public, serving, without distinction, all the people, including manufacturers, domestic consumers, traction lines and municipalities. In the truest sense of the word it is a Public Service

Business, and as such there can be no doubt of the power of the Government to exercise over its service and charges the most minute and continuous supervision and control. The only restrictions upon this power is that there must not be confiscation of the property in which capital has been invested.

There has been a great deal of discussion as to the relative legal rights of the Federal and State Governments as bearing on water powers. These I will not attempt to discuss. So far as I have been able to ascertain, the majority of investors have no particular preference in the matter; but are vitally interested in having their public service investments regulated by only one authority.

Contrary to the general belief the charges which the Government, State or Federal, may make for the privilege of using the water powers is not a matter of material importance to the power companies, so long as such charges are not so great as to make it impracticable for the power company to compete with steam or gas producer plants, or with other water power companies exempt from such special tax. It may seem desirable to the Government that an annual charge be made. I believe that so long as the charges are not so high as to prevent the substitution of water power for fuel consuming power, the matter is entirely one of equitable taxation, in which the only interested parties are the Government and the local community paying the tax.

While our legislative bodies may well enact a law to limit the tenure of a private individual (whose business cannot be regulated) in connection with the development and use of water power on the Government domain, I can conceive of no reason for similar restrictions in the use of water power which the Government elects to develop and use, not directly, but indirectly, through its agent the Public Service Corporation. In such a case the Government has power to supervise, regulate and control every phase of operation.

Many of the largest and best unused water powers to-day are upon the so-called navigable streams. An investor is asked by the local people to join in providing capital to develop such powers. He is at once confronted by the necessity of securing an act of Congress authorizing the construction of a dam across the rapids of the so-called navigable stream, rapids over which in many cases no boat has ever passed, nor probably ever will pass until locks are constructed. In demanding that the power developer shall construct and present to the Government an elaborate system of locks as part of the construction of the dam, the Government overlooks the fact, not

only that such construction must ultimately be paid for by the community served by the power company, but also that the very building of the dam across such rapids will relieve the Government of the great expense of creating the necessary pond over the rapids.

Where there is this close competition between the relative economies of water power and fuel consuming apparatus, and where the adoption of steam, oil or gas means a large unnecessary consumption of non-replaceable fuels, is it not a pity that every possible power at the command of the Government, Federal, State and local, is not exerted to the utmost to secure the adoption of the water power system and thus save the fuels? If it is necessary for the State or local communities most directly affected to pay a bonus equal to the value of the fuel which the same amount of steam or gas-producer apparatus will consume in one, two, or three years; then, as a citizen and taxpayer, I would gladly vote for both of these propositions.

Practically all of the discussions in the public press to-day, and so far as I know, all the laws that have been passed, and many bills introduced but not passed, regarding limited tenures and other onerous restriction as to water powers, have applied only to the power generating station. In practically every case the investment in the step-up, transmission, step-down and distributing plants is many times larger than the investment in the generating plant. It is therefore absolutely essential, if capital is to be secured at reasonable rates, that every part of the hydro-electric plant (which includes step-up, transmission, step-down and distributing plants) be treated as a whole.

It is only necessary for any one to read the laws and the bills introduced in Congress, to realize that our legislators still have in mind the idea of the early grist mill or factory type of water power, where the energy is generated in small units and used entirely upon the premises. Formerly the people located immediately around the water power sites; now we take the water power to the people, the transmission system being as necessary as the power plant. In other words, commercial hydro-electric development has progressed, but our water power laws have not. As a result, it is impracticable to obtain money for power development on the public domain, except from the most speculative kind of investors. The 50 or 100 percent increase in the rates which must be paid for money to induce such investment on the public domain constitutes a tax resulting from unwise laws which must be paid by the power consumer.

Limited tenures may be well enough in the case of the development of a water power in connection with a private business which the Government has no right to regulate; but advanced thinkers on the subject, I believe, all agree that, next to revocable permits, limited tenures are the most fallacious and harmful of all the present-day popular notions, when applied to a water power, or any other development made for the public benefit. Limited and uncertain tenures are the greatest of all obstacles in the way of economical and quick development of water powers for public use.

A power developer may have three or four times as large an investment in his distributing system (entirely off the Government domain) as in the generating station on the Government domain. The whole distributing system would necessarily be made inoperative and useless by the failure to secure a renewal of the original limited tenure for the generating station.

There is good reason in many private contracts, which cannot be changed without the consent of both parties, to doubt one's ability to provide for every contingency for 50 years, or even a much shorter period. But why, and in what possible way, can this affect a public service corporation, a servant of the people, an agent and instrument of the Government, created, kept alive, controlled and regulated, not every 50 or 20 years, or one year, but every day of its life and for all time, down even to the most minute detail of its business, by its creator, the Government? And if it is conceded that the Government has this right to regulate a public service corporation every day of its life, why should the Government weaken its position by making fifty year tenure contracts which tie its hands for that period? Why is not this an absolute and complete answer to all advocates of limited or uncertain tenures?

Just a few words on rate competition from the investor's standpoint. In the communities, such for instance as Massachusetts and Wisconsin and New York, where there has been the most searching and progressive thought on this subject, the advent of a competing public utility corporation is prohibited unless public necessity therefor is clearly shown. Rate competition between public service corporations means rebates, discriminations, and special favors. This is a practice which both Federal and State laws and commissions are wisely attempting to eradicate; and Martin A. Knapp, now Presiding Judge of the new Commerce Court, in referring to the old ideas of Public Service competition, has well said:

> "That it is a mistaken policy I am fully persuaded. For the power to compete is the power to discriminate. It is out of the question to have present the element of competition and at the same time try to regulate rates."

Hydro-electric power operations in any one zone, district or city should be strictly limited to one company, unless there appears to the Governmental authorities an unquestionable public necessity for something different. This is the practice already, not only in the more progressive states, but also in European countries. Aside from the better service and the economies in operation which can by this plan be secured for the benefit of the public, how can the people expect to get additional money from the investors unless they protect the money which the investors have already expended?

If there are carried out all of the plans which I have mentioned for the regulation of public service corporations and for restraining unnecessary competition by either Government or private capital, there will unquestionably be a quick, large, economical and thorough development of the water powers.

To my mind the only way this water power question can be promptly and correctly solved, as a fuel conservation problem or otherwise, is by so educating the people on every phase of the subject that they will not only support and approve, but will insist upon the adequate and sane legislation now so much needed. Can we not learn much from our conservation friends if we recognize that their aims are high? Cannot our conservation friends learn much from us if they appreciate that our practical experience is of value, and we, too, are honestly seeking the correct solution of the common problem?

VARIOUS PHASES OF LOW-PRESSURE TURBINE WORK*

EDWIN D. DREYFUS

THE low pressure turbine has become such an important economic factor in power-plant engineering, that a survey of its possibilities and present uses, should be in no small degree interesting and profitable. A great many low-pressure turbine plants have been installed, varying widely in their general character, but having one common feature; *i. e.,* that the economic results achieved were immediate and marked. While the low-pressure turbine has been most generally used for increasing the capacity of plants consisting of reciprocating steam engines which are in good physical condition, there are sundry other special applications which, although less usual, are perhaps correspondingly the more interesting.

In view, therefore, of the important developments which have taken place, it is a safe assertion that the low-pressure turbine may be economically applied for increasing capacity in all types of plants using steam engine power and, ordinarily, irrespective of working conditions or location of the apparatus. Its adoption truly establishes a rehabilitation of the reciprocating engine; first, in preserving its appraised value and minimizing the total plant investment and second, through combined operation, improving the steam economy to the present high standards.

If the design of the turbine and its auxiliary mechanism had been suitable for but a single rigid condition, the progress of the low-pressure turbine would have been considerably retarded. But there are a great variety of conditions to which the turbine may be adapted, and these provide the intended scope of this paper. The theory and demonstration of the utility of the low-pressure turbine will, therefore, be only briefly considered in the accompanying appendix, since they have heretofore been well discussed.

CLASSIFICATION OF LOW-PRESSURE TURBINE INSTALLATIONS

a—Addition to a well-arranged and symmetrical alternating or direct-current power-generating station, condensing or non-condensing.

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*A paper read before the Providence Assoc. of Mech. Engineers, Feb. 28, 1911.

b—Extension of poorly-designed stations with dissimilar units.

c—Increased capacity for mills driven mechanically by main engine.

d—Mills with widely distributed engines, demanding more power.

e—Conservation of waste in intermittently-operated and reversing engines.

f—Variable alternating-current electrical load for low-pressure turbine with uniform mechanical or direct-current load for engine and vice versa.

g—Utilization of gas engine waste heat.

CHARACTERISTICS OF SYSTEMS

The nature of both the application of and the demand for continuous power from the low-pressure turbine has, in the different cases above enumerated, evolved the following systems:

1—Turbine without governor.

2—Simple low-pressure turbine having governor control, with supplementary live steam admission valve.

3—Use of synchronous motor providing an electrical and mechanical tie with the main belt or rope wheel engine.

4—Governor operating valve by-passing steam to condenser.

5—Heat regenerators and accumulators.

6—Mixed flow turbine with high-pressure element.

7—Heat storage systems.

COMBINED ENGINE-TURBINE UNIT

This division proposes to cover what is to be considered the simplest type of plant, where the low-pressure turbine, with the engine, forms either a compound or triple expansion unit. The electrical interlocking of the engine and the turbine generators allows all governing to be cared for by the one regulator on the engine, the low-pressure turbine performing similar to a low-pressure cylinder with a fixed cut off. Fortunately for the compound engine (of large cylinder ratio especially), a variable back pressure is imposed, which obviates objectionable pressure looping and

pounding of the exhaust valves on light loads. In addition to this mechanical consideration, a gain in efficiency of about five percent is realized, due to the more economical intermediate pressures established for the varying loads, as brought out in Fig. 1. Evidently with a long and non-air-tight exhaust system, variable pressure operation would not be recommended. The practice of allowing the pressure between the engine and the turbine to fall below atmosphere, was looked upon by some designers and engineers with disfavor at the outset, but experience gained in many low-pressure turbine plants has confirmed its advisability. As an example of this application, Figs. 2 and 3 show plants originally non-condensing and condensing where turbines without governors have been installed.

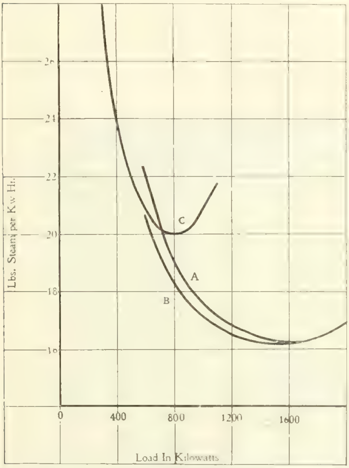

FIG. 1—WATER RATES FOR 22 AND 44 BY 42 INCH CORLISS ENGINE AND 750 KW LOW-PRESSURE TURBINE

A—Curve showing combined water rate with constant exhaust pressure on engine.

B—Curve showing combined water rate with variable exhaust pressure.

C—Water rate of engine alone operating at 150-lbs. guage pressure dry steam, 26-in. vacuum.

It may at first seem logical, from the view point of steam economy, for the combination engine and turbine unit to be stipulated for new power equipments. However, the question of ultimate costs must be considered and, owing to the greater initial maintenance and operating expense, we find ourselves obliged to accept the simple turbine, especially for electric generation, and with possible exceptions where favorable disposition of both mechanical and electrical load may exist.

The preceding discussion relating to constant vs. variable exhaust-pressure operation, applies chiefly to the normal condensing cylinder ratio of four to one. For non-condensing compound cylinders, the mechanical advantage of the latter system more or less vanishes. On the other hand, with cylinder ratios exceeding

four to one, looping difficulties assume a serious aspect. Frequently condensing cylinders have been bushed to obviate trouble with the exhaust valve, more particularly where constant back pressure is maintained. As alteration of the engine invariably entails heavy expense and interruption, it is generally to be avoided, If necessary, low-pressure turbines may be installed for initial pressures of eight pounds absolute or less. In fact, they have been built to begin expansion from the terminal pressure in a compound engine and carry it out economically to the lowest practicable back pressure. Obviously such a turbine would not be commercially at-

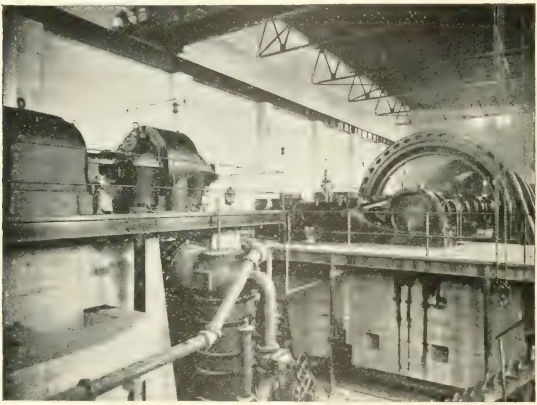

FIG. 2—1 000 KW LOW-PRESSURE TURBINE USING STEAM FROM HORIZONTAL ENGINES
Colorado Springs Electric Company, Colorado Springs, Colo.

tractive. In large ratio engines, these considerations have induced a study of ways and means to obviate the expense of greatly modifying the engine. It has been found possible to do this by advancing the point of release in the low-pressure cylinder and simultaneously retarding the point of exhaust valve closure. The result of removing the negative work, both from over expansion and compression, may be seen in Fig. 4. Actual drawings and the steam diagram of a four and one-half to one engine were employed in proving the merits of this scheme. In the combined diagram (upper half of Fig. 4), the heavy lines represent the nature of the

indicator card desired. The dotted lines complete the card that would obtain with normal cut-off in the high-pressure cylinder under the conditions for which the engine was originally designed, and the dot and dash lines show the looping that would be encountered with atmospheric back pressure if no changes were made.

When the expansion in the low-pressure cylinder has reached approximately the re-established back pressure (17 lbs. abs.), release takes place, and the steam pressure in the cylinder for the remainder of the stroke, will correspond to this back pressure. The

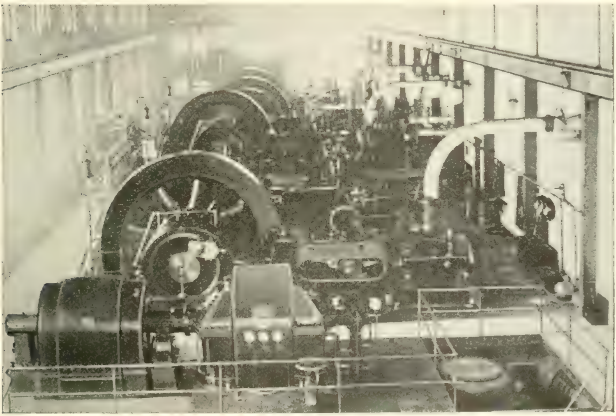

FIG. 3—LOW-PRESSURE TURBINE OPERATED BY EXHAUST FROM HORIZONTAL ENGINES
Western Ohio Railways Company, St. Marys, Ohio.

simplest means of accomplishing these results for the engine in question, was found by changing the angular position of the valve on the stem, as illustrated in the dotted and full lines. With the original valve setting shown in dotted lines, the exhaust opening does not occur until the piston nears the end of its stroke, but by being advanced to the point shown by the heavy lines, expansion is discontinued and looping avoided.

All that may be required is a new valve stem, on account of the new location of the key seat. Besides, it may be necessary to increase the valve port by chipping off the metal at D and D_1,

Fig. 4, to prevent cramping of the exhaust on the return stroke. Early release simultaneously accomplishes a delay in the closing of the exhaust valve, so that over-compression, shown in the cross-hatched area *B*, is avoided. This particular engine possesses a large amount of lap that simplifies the problem very much. While this method of operating may not prove feasible in all designs of engines, it is practicable with the majority.

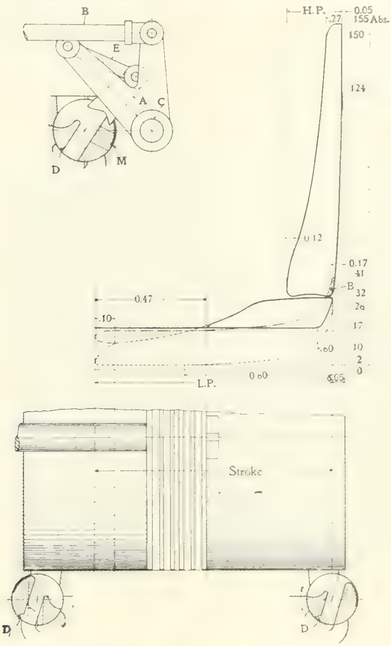

FIG. 4—INDICATOR DIAGRAM AND SKETCHES SHOWING VALVE GEAR CHANGES ON HIGH-RATIO COMPOUND ENGINE

THE USE OF AN AUXILIARY LIVE STEAM ADMISSION VALVE

Where sufficient exhaust steam is constantly available for operating the low-pressure turbine, the simple design without governor is preferable. Adequate provision is obviously essential in the power plant to insure continuity of service. With the low-pressure turbine constituting only a small part of the entire generating capacity, the reduction or cessation of its output, due to a deficiency in the exhaust steam supply, may occasion little embarrassment in operation. But when, as frequently found, the addition of the low-pressure turbine *doubles* the possible output of the original equipment and the actual load is increased correspondingly ,then some factor of safety should be introduced. This is ideally secured by employment of a throttling live steam admission valve. Ordinarily, for plants satisfactorily maintained, the occasion for operating the low-pressure turbine on live steam, is rare, and consequently the consideration of economy during such periods may be

safely neglected. *It would not overtax the capacity of the boiler plant,* in any event, as it may appear at first, as the turbine would continue to develop power with about the same steam consumption as previously, improving probably six percent from the resulting superheating. Even with a rapidly fluctuating main-engine load, it proves advantageous. Boilers cannot be regulated sufficiently to provide for sudden decrease in the steam used, the pressure relieving through the safety valve. Thus the low-pressure turbine equipped with the auxiliary valve, will just absorb the steam otherwise wasted to the atmosphere. Hence the controlling of this valve, performs a function parallel, in a sense, to the regenerator, and

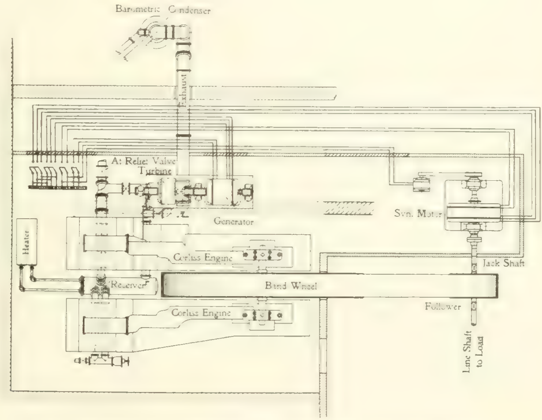

FIG. 5—PLAN OF LOW PRESSURE TURBINE SYSTEM USING SYNCHRONOUS MOTOR TIE

with maximum simplicity. It is plain no improvement will result in employing an efficient high-pressure element in the turbine under these conditions. Both the main atmospheric and auxiliary live steam valves are of the throttling type. The interposition of a regulating valve between the engine and the turbine, does not remove the possibility of variable-pressure operation. Adjustment of a counter-balancing spring on the low-pressure turbine governor, may be made so that the admission valve in the main exhaust line will remain open, unless the synchronous speed of the turbine should increase a predetermined amount above that of the engine, obviating throttling losses over practically all ranges in load.

EMPLOYMENT OF A SYNCHRONOUS MOTOR TIE

Manifestly a positive interlocking of the low-pressure turbine with the main engine must be effected in order that direct compounding with the engine may be accomplished. In electric-generating stations, the problem is immediately solved through generators of identical characteristics, the synchronizing force, in alternators particularly, establishing a certain bond. In mills mechanically driven, the absence of an immediate coupling of the engine and low-pressure turbine, has been circumvented through the provision of a

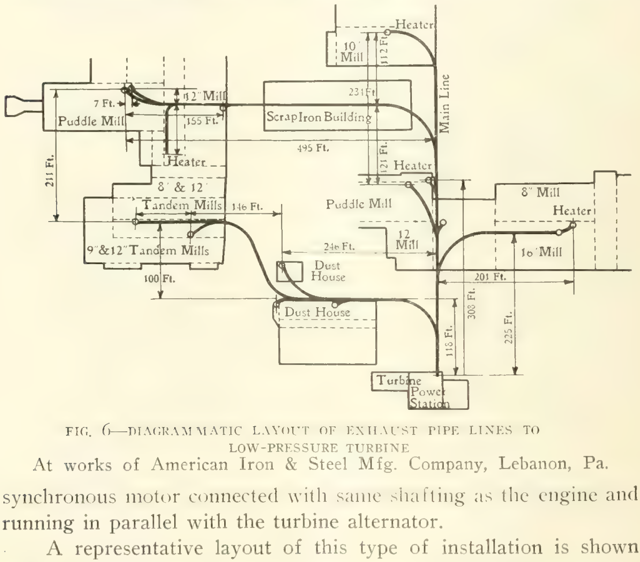

FIG. 6—DIAGRAMMATIC LAYOUT OF EXHAUST PIPE LINES TO LOW-PRESSURE TURBINE

At works of American Iron & Steel Mfg. Company, Lebanon, Pa.

synchronous motor connected with same shafting as the engine and running in parallel with the turbine alternator.

A representative layout of this type of installation is shown in Fig. 5, in which all essential apparatus is included. The main advantage in this arrangement is the interchange of load provided between the engine and turbine. An external electrical load may also be supplied to the extent of 75 percent of the capacity of the turbine and motor. In this way the synchronous motor may alternately serve as motor or generator. Through the joint electrical and mechanical coupling, the governor for the turbine may be omitted, regulation being accomplished entirely by the engine. Here the turbine inlet and engine back pressure automatically adjust them-

selves with the load, contributing towards the best mechanical and electrical performance.

WIDELY DISTRIBUTED ENGINES

During the early period of the development of the low-pressure turbine field, it was deemed requisite that the source of exhaust supply be fairly concentrated and adjacent to the most desirable location for the turbine. This was especially so with a diversity of small engines. However, attractive economies have been revealed at several industrial works which have inaugurated installations of ex-

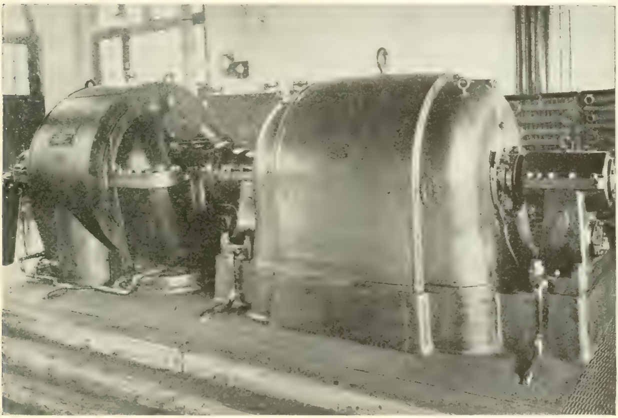

FIG. 7—1 000 KW LOW-PRESSURE TURBINE SET
At works of American Iron & Steel Mfg. Company, Lebanon, Pa.

traordinary interest. An example is shown in Fig. 6, in which case the exhaust of thirteen widely-separated non-condensing engines has been conserved and delivered through the extensive "tributary" piping system illustrated to the low-pressure turbine, Fig. 7, located in a central power house. The value of the low-pressure turbine thus becomes very significant when, as in this case, an additional output of 1 000 kw can be generated without increased expenditure in fuel. This system comprises 2 475 lineal feet of piping, varying in diameter from five inch feeders to a 28-inch header, terminating in a large oil and moisture separator eight feet in diameter and 16 feet in depth. Suitable expansion joints are provided at required

intervals, and all piping is carried overhead, lagged, and supported on pipe frame work.

Conservative estimates show that an electrical horse-power year with these conditions of operation, is being produced in the low-pressure turbine plant at $5.50, including all charges. In an equivalent high-grade condensing steam station, corresponding power costs would range from $16 to $45 with coal varying from $1 to $6, and $22 to $35 in a gas plant for the same conditions and range of coal prices.

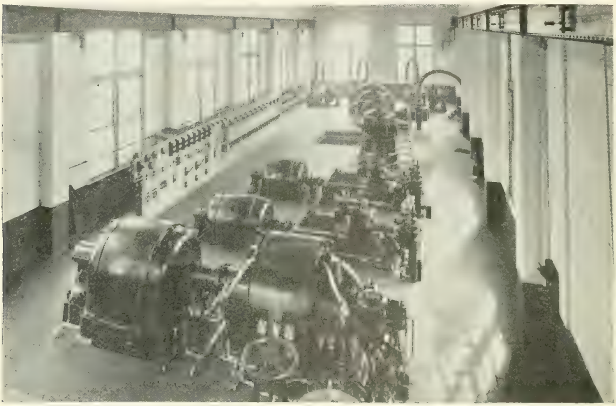

FIG. 8—1 000 KW LOW-PRESSURE TURBINE SET WITH GOVERNOR (IN FOREGROUND)
Pressed Steel Car Company, McKees Rocks, Pa.

At the Pressed Steel Car Works, McKees Rocks, Pa., a low-pressure turbine was installed in 1908 to operate on the exhaust from a non-condensing pumping and compressor station adjacent to the power house. Later a 500 kw low-pressure turbine of the same type was added. An interior view of this plant is given in Fig. 8, showing the 1 000 kw low-pressure turbine first installed. It is very seldom that any part of the high-pressure equipment (now held in reserve, and shown in the background) is used, excepting in extremely cold weather, when large quantities of the exhaust steam are diverted to the shop heating system. This clearly evidences a large reduction in fuel consumption.

There are two objects in showing, in Fig. 9, the 750 kw turbine installed by the Lorraine Mfg. Co., Pawtucket, R. I. Firstly, it possesses the type of governor described in this division, and secondly it is operated in parallel with the main engine through synchronous motor control. In this installation a large external electrical load is supplied alternately or jointly from the engine and turbine. On the other hand, the turbine assists the engine in event of a heavily increased mechanical load.

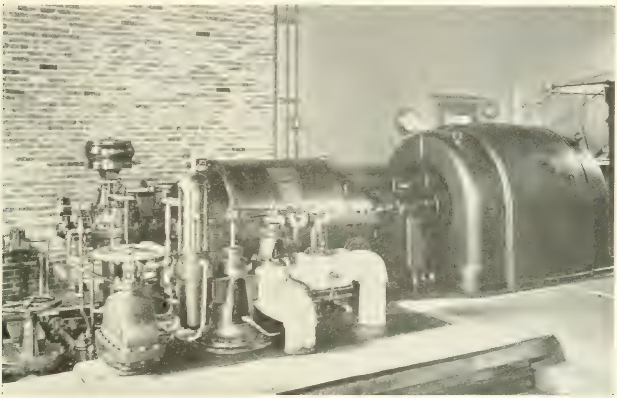

FIG. 9—750 KW LOW-PRESSURE TURBINE SET WITH GOVERNOR
At works of Lorraine Mfg. Company, Pawtucket, R. I.

ENGINE AND TURBINE LOADS DISSIMILAR—TURBINE NOT CONSUMING ENTIRE EXHAUST

There are specific cases where the low-pressure turbine may be profitably installed in connection with a reciprocating engine condensing plant without the entire amount of engine or pump exhaust being utilized in the turbine. If the surplus steam over and above the quantity required by the turbine during any period be permitted to escape at a pre-determined pressure, a certain loss in energy would be occasioned, which might otherwise be avoided through the medium of a partial vacuum produced on the high-pressure apparatus. To satisfy this requirement, a governing system has been developed for low-pressure turbines which controls the flow of exhaust steam in such a way as to continually deliver to the

turbine the amount of steam necessary to carry its load and to by-pass to the condenser any existing excess. Manifestly the back pressure on the engine always corresponds with the turbine inlet pressure which, in turn, is proportional to its load. Consequently, that part of the steam passing through the turbine, is used with a relatively high degree of efficiency, while the remainder is throttled through only a small range in pressure by the governor valve, occasioning a minimum loss from free expansion of the excess steam.

The advantages of this arrangement are:

a—Ability to apply a low-pressure turbine economically to high-pressure apparatus with different load characteristics.

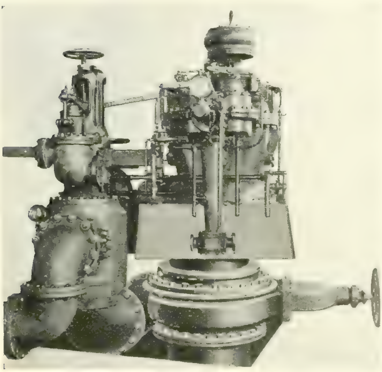

FIG. 10—VIEW OF GOVERNOR END OF LOW-PRESSURE TURBINE WITH GOVERNOR CONTROLLED BY-PASS VALVE

b—Obviates the necessity of having the high-pressure engines operate continually at the back pressure required to carry maximum load on the turbine, as in the case where a governor controls only the supply to the low - pressure turbine. With the latter type at loads less than rating on the turbine, the excess steam would escape at relief pressure, entailing a corresponding loss in energy. It will, therefore, be unnecessary to cut in and out the engines serving the low-pressure turbine with the new valve to accommodate the load on the turbine.

c—Extension of existing capacity to secure high efficiency in the new and old equipment.

d—Simplification of station arrangement, less piping and floor space; one condenser for steam passing through high and low pressure elements.

The first two items are peculiar to this system of governing, while the last two are common to all.

Assembly—The arrangement of the by-pass valve connected to the turbine, is shown in Fig. 10. This is a detail view of one of the two 600 kw units of the Havana Railways Company.

An arrangement plan for a turbine installed to operate on the exhaust from a cross-compound, direct-current unit, is shown in Fig. 11, which explains the principal features embodied in the above scheme.

Economy—This method of operation is best suited to cases where high-pressure units operate at practically constant load, or a

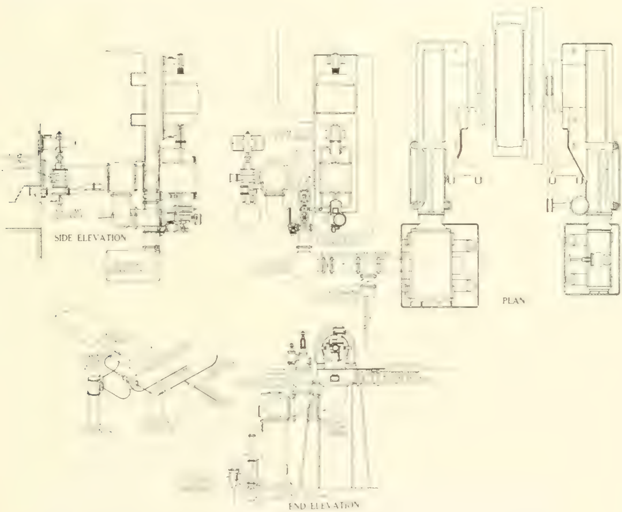

FIG. 11—ARRANGEMENT OF ENGINE AND LOW-PRESSURE TURBINE WITH BY-PASS VALVE

system of engines, pumps and compressors, exhausting in the aggregate, a nearly uniform supply of steam.

If the turbine does not constantly require all the available exhaust from the high-pressure units, the latter may be made to reap the benefit of reduced back pressure when the turbine is carrying a light load. A turbine at no load would require an inlet pressure of about five pounds absolute for a vacuum between 26 and 27 inches, and correspondingly lower for higher vacuum. As the im-

portant feature of by-pass governing is to maintain automatically a pressure in the exhaust line from the engine equivalent to the required inlet pressure at the turbine, the engines would then exhaust at about five pounds absolute when the load falls off on the turbine. It is safe to say that the gain of the simple engine will be approximately proportional to the decrease in back pressure.

Illustration—Since a simple engine should have a mean effective pressure of 50 lbs., each pound reduction in back pressure would produce an improvement close to two percent. As the back pressure will be lowered ten pounds approximately when the turbine is carrying no load, the corresponding betterment is roughly 20 percent. Hence, between the limits of the low-pressure turbine taking its full-load steam and producing over 100 percent better results, and its no-load consumption, the fuel saving will vary from 20 to 50 percent.

The foregoing discussion applies mainly to small apparatus where the saving must necessarily be considered in order to have any material effect upon the general economy of the plant. Where large units exist and fuel is an appreciable factor in the production of power, the low-pressure turbine, with by-pass operation, may introduce important economical returns. Such cases occur principally in connection with existing direct-current railway power plants where extension becomes necessary for outlying rotary sub-stations. The service in the bordering and sparsely settled territory, is naturally infrequent in comparison with important streets and centers. Consequently, the alternating-current low-pressure turbine units would operate on a comparatively variable load, and the by-pass system will thus effect the most economical station results. This is analogous to the conditions surrounding the installation of low-pressure turbines at the Havana Railway plant.

At present the prevalent type of blowing engines in the steel mills have compound Corliss cylinders. It is practicable to install this particular low-pressure turbine system to furnish the varying power requirements of the mills and operate with high economy in connection with the constantly loaded blowing units.

In low-pressure turbine installations with by-pass governors, *it is not necessary that the turbine be large enough to utilize all the exhaust of the engine at, say, atmospheric pressure.* The most desirable intermediate pressure and the percentage of the exhaust to pass through the turbine is, to a great degree, elective.

In Fig. 12, the total steam line *C* of the 750 kw low-pressure turbine, is given, and also the corresponding intermediate pressure line *E*, one pound being added to the turbine inlet pressure for receiver drop. In addition, the total steam line *D*, of a 1 200 kw cross-compound direct-current engine unit is included, differing, however, from the customary representation, in that it is plotted for constant output against the varying back pressures established by the by-pass governing system from no-load to full-load on the turbine. Manifestly, where lines *D* and *C* cross, the turbine is consuming the entire engine exhaust. To the left of this point, the disparity between the two shows the quantity of steam by-passed, and to the right, the surplus steam admitted by the live steam valve to carry the overloads on the turbine. Reduced to the unit water rate, the gain becomes very apparent, as shown in Fig. 13. The engine rate obtaining for blowing or direct-current units, with the average condition of maintenance, is about 20 lbs. per kilowatt-hour, as indicated by the broken line *H*. Curve *G* shows the equivalent combined water rate with variable load on the turbine, determined from the total steam lines *D* and *C*, Fig. 12, the combined output being read on the lower horizontal scale. The improvement secured by this method of operation, is therefore, from 25 percent at full load on the turbine, to approximately 10 percent at half-load. If it had been assumed that the proposition would have demanded a larger low-pressure turbine capacity, the showing for combined operation with by-pass governing would have been still more prominent.

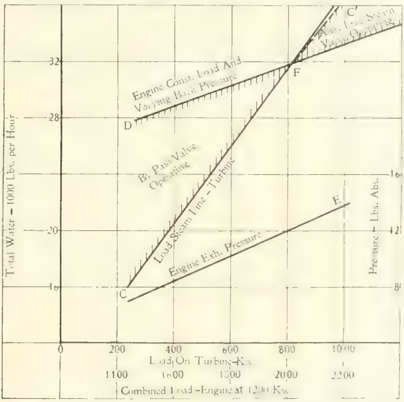

FIG. 12—PERIODS OF OPERATION OF BY-PASS AND AUXILIARY LIVE-STEAM VALVES

Total steam consumption of compound engine operating at constant load, 7 200 kw and 750 kw low-pressure turbine with by-pass governor and varying load.

With a direct operating governor admitting exhaust steam to

the low-pressure turbine according to the load requirements, the atmospheric valve would be set to carry the peak on the low-pressure turbine, and consequently at all loads less than rating on the turbine, part of the steam would be wasted. Obviously the economy of such an installation would not be so good as that obtained with the by-pass system. If a complete expansion turbine be installed to meet the power extensions, the *average* plant steam economy with the engine at 1 200 kw and the turbine load varying would agree closely with curve *J*.

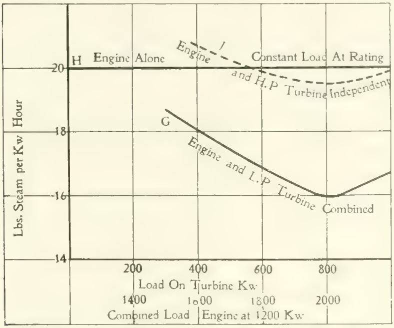

FIG. 13—COMBINED WATER RATE, ENGINE LOAD CONSTANT AT 1 200 KW, TURBINE LOAD VARYING

Showing advantages of by-pass governing system.

There are evidently, many additional considerations which may enter the plant problem, but it is quite apparent that where approximate conditions, as above noted, prevail, considerable opportunity exists for increasing the operating efficiencies along the lines presented.

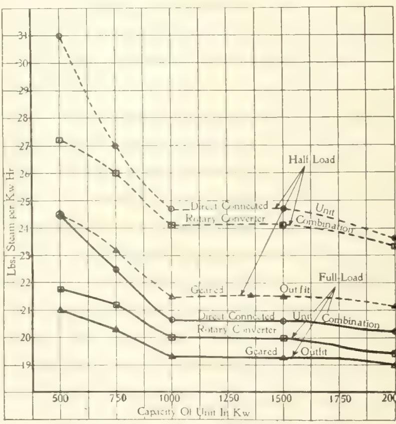

FIG. 14—COMPARATIVE STEAM CONSUMPTIONS OF THREE ARRANGEMENTS OF DIRECT-CURRENT TURBINE SETS, 150 LBS. PRESSURE, 28-INCH VACUUM

SUPPLYING A DIRECT-CURRENT DEMAND

Not infrequently the power developed in the low-pressure turbine is to be consumed in direct-current machinery or special applications, such as

electrolytic processes, etc. Direct-current generators are inherently slow-speed machines and hence it is not ordinarily feasible to couple them directly to steam turbines. To build and

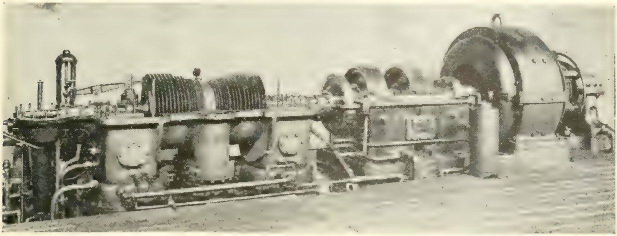

FIG. 15—GEARED DIRECT-CONNECTED UNIT
With covers of gear case and turbine removed.

operate direct-current generators, especially for high speeds, requires the highest degree of skill, material, workmanship and attendance to secure satisfactory operation and economy. There has

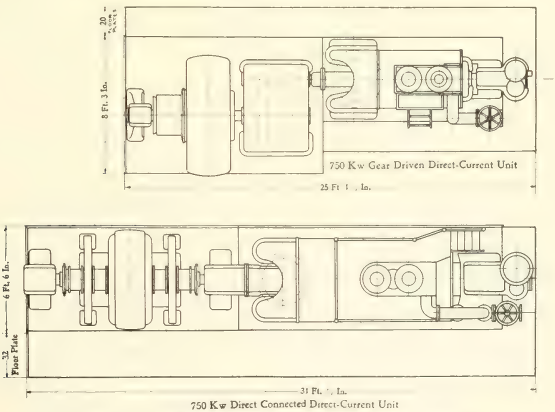

FIG. 16—COMPARATIVE FLOOR SPACE DIMENSIONS
Of 750 kw direct-coupled and of 750 kw geared direct-current units.

consequently, been an insistent demand for the employment of standard, direct-current apparatus, which has recently been satisfied through the use of turbo-alternator and rotary combinations

and the Melville-Macalpine flexible reduction gear. Incident thereto, a substantial betterment in economy is derived, as shown in Fig. 14. A 500 kw direct-current low-pressure turbine unit with reduction gear, is shown in Fig. 15, and Fig. 16 shows the comparative floor space of the two types of direct-coupled units, both of 750 kw capacity.

INTERMITTENTLY OPERATED AND REVERSING ENGINES

An important auxiliary for the low-pressure turbine has been devised in the steam regenerator and accumulator which averages the irregular supply of exhaust from engines, producing a fairly constant flow of steam to the turbine. The economies thus effected are well known. The turbine is enabled to produce a constant out-

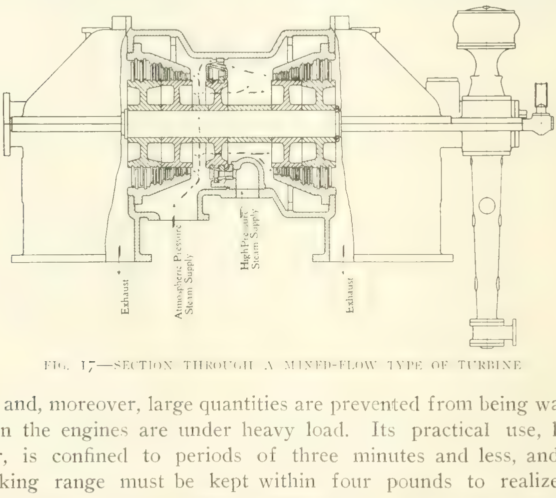

FIG. 17—SECTION THROUGH A MIXED-FLOW TYPE OF TURBINE

put, and, moreover, large quantities are prevented from being wasted when the engines are under heavy load. Its practical use, however, is confined to periods of three minutes and less, and the working range must be kept within four pounds to realize the desired results. For constant operation of the engines, the apparent advantage in relieving the pulsations of steam flowing to the turbine, lies in permitting a slightly smaller turbine to be installed and operated at more efficient load. This, however, is counter-balanced by the greater expense of the regenerator installation and its losses.

PERIODIC CESSATION OF EXHAUST SUPPLY

Conditions may be encountered at times conducing toward the use of a low-pressure turbine with the exhaust supply interrupted

for certain periods, and where the turbine must continue in operation. Such requirements have evolved the development of a mixed flow design, Fig. 17, possessing good economy with either high or low-pressure steam. But the advantage of this type may be easily confused. The low-pressure turbine, as understood, may be installed without governor, with auxiliary throttling valve, or of mixed flow construction, containing a high-pressure element. Evidently there are conditions obtaining in which any of the three arrangements may prove superior in practical operation. It is now well appreciated that the ideal application of the low-pressure turbine is fulfilled when it serves as a low-pressure cylinder of a reciprocating engine, with all unnecessary parts, such as regulator, governor, valves, or high-pressure elements, eliminated.

For infrequent emergency operation, the simplest device under governor control to insure continuity of service either on high or mixed pressure steam (throttled), commends itself. With definite periods of use of a high-pressure source, due to deficiencies or cessation of exhaust supply, a comparatively efficient mixed flow turbine comes into prominence, *providing more efficient high-pressure sets are not held in reserve.* Therefore, where the load is to be carried on high-pressure steam for a larger part of the elapsed time, an economical high-pressure condensing turbine should be installed. Selecting a mixed flow type simply because the turbine uses steam expansively from boiler pressure to the maintained vacuum and may be had at very little increased cost, is very liable to create a false idea of its commercial economy.

Systems of operation which affect the selection of the type of low-pressure turbine, may be classified as shown in Table I.

In the subdivision *A, Case 1,* there are instances in steel mill practice where the boilers are forced to full capacity in order to supply the engines their full quota of steam without a large drop in pressure, in spite of the fact that the blooming, plate or rail mills may be shut down temporarily waiting for ingots. During these periods the steam blows off to the atomsphere and no advantage exists in providing a high-pressure element in the turbine.

When the boiler capacity can be controlled in exact conformity with the demand, a mixed-flow turbine has an advantage for certain periods of intermittent exhaust supply. But where the engines exhausting to the turbine or turbines are not operating for a considerable time of the year, it remains a problem whether it is worth

while to install the more complex mixed-flow turbine and obtain 30 percent better efficiency with a fuel which is a by-product and otherwise wasted, as in blast furnace practice. As the labor with gas-fired boilers may not be a serious factor, and furthermore as the continuation of a boiler in service causes no greater depreciation than alternate heating and cooling from inconstant use, the mixed pressure type, *Case 2*, may be favored. However, if fuel cost

TABLE I—SYSTEMS OF OPERATION

Case 1	High-pressure engine and low-pressure turbines supplying different loads. All low-pressure steam used at constant pressure slightly exceeding atmosphere.	A	Boilers maintained at normal steaming rate to serve heavy instantaneous demands.	
		B	Boilers controlled to accommodate existing loads.	
		C	Low-pressure turbine continued in operation with high-pressure units out of service, depending on length of periods involved.	1 Fuel, a waste product.
				2 Purchased fuel.
Case 2	Parallel operation of all generating apparatus. All low-pressure turbines working preferably with variable pressure operation.	A	Low-pressure turbine installed primarily for economy.	1 Large station, many units.
		B	Installation increased primarily for capacity, improved economy incidental.	Small station, single or few units.
		C	Effect of total station capacity on selection.	

must be reckoned with and the period of operation on high-pressure steam is considerable, a further reduction in steam consumption may be warranted.

Case 1 applies mainly to steel mill and similar industries. *Case 2* represents conditions generally obtaining in power plant service. There are, obviously, exceptions, as for example, where the main units operate both alternating and direct-current generators, and perhaps other peculiar local circumstances, but the classi-

cation given covers the field broadly. Sub-division *A*, *Case 2*, would be best satisfied by a simple low-pressure turbine, as the implication follows that there is sufficient protection in spare high-pressure units for emergencies. In *B* there is probably plausible reason for the adoption of mixed-flow turbine, especially for units under 500 kw capacity. But for larger proposed installations, it will in all probability, prove most profitable to install a simple low-pressure unit to work on all the available exhaust and an efficient complete expansion unit to supply the remaining increase in load.

It is a comparatively simple problem to weigh in balance the merits of the different low-pressure turbine arrangements. Thus far, there have been but very few installations in which the limited advantages of the mixed flow principle could be realized.

UTILIZATION OF GAS ENGINE WASTE HEAT

Since the advent of the low-pressure turbine, it has become feasible to economize the waste heat of the gas engine in exhaust heaters and utilize the energy directly in the turbine without the introduction of high-pressure boilers and coal-burning furnaces in the plant. Based upon the actual performance of the component elements of such a plant, the following results may be achieved:

> *For Continuous Operation—a*—Employing the exhaust heat only, six to eight percent heat saving over the existing economy of the gas engine.
>
> *b*—Abstracting heat from both the engine exhaust and jackets, 10 to 14 percent.
>
> *For Peak Load Operation—a*—Storing heat from the exhaust over periods several times the duration of the peak, makes it possible to sustain heavy overloads on the plant, resulting in appreciable reduction in investment for the maximum demand, of 15 to 30 percent normally, in addition to fuel saving.
>
> *b*—Operating with intermittent storage, the variable swings may be loaded in the turbine, enabling the engine and producers to operate under most favorable conditions. Ultimate improvement about 15 percent in heat consumption and 12 percent in investment. Moreover, the auxiliary low-pressure turbine would act as a reserve unit to relieve, partially or fully, any temporary embarrassment of the engine.

Heat Storage—If a widely changing load should be experienced, providing a *low loading factor*, the installation of the auxiliary plant *for continuous operation*, may perhaps prove inadvisable as the fuel expense may bear only a small relation to the total cost. But by accumulating the *primary* waste heat in a storage system and utilizing it in a simple and comparatively inexpensive low-pressure turbine auxiliary, this arrangement will aid in reducing the capital charges.

Power, in the form of heat, may be stored by an increase in thermal head of the storage medium, exactly the same as water power by increasing the hydraulic head. Heat storage is not new, as it has been applied in steam plants where hot feed water is accumulated for peak loads, and similarly in the principle of the steam regenerator.

The conditions where the auxiliary low-pressure turbine may be profitably installed, may be divided mainly into two classes, viz:

I—Low-pressure turbine operating continuously with uniform load on the plant, as exists in most industrial works.

II—Widely varying load on plant, with the low-pressure turbine in conjunction with a heat-storage system, serving only the peak-load swings.

a—Fixed peak, as in central lighting stations.

b—Irregular peak, such as on an interurban railway with infrequent service.

Projects of this character have been actually applied abroad, and their economic possibilities have been treated extensively by the author in an independent paper.

ECONOMY RECORDS

One user of a low-pressure turbine of 300 kw capacity, testifies:

"The station factor was 34 percent previous to the installation of the turbine, and 21 percent since installation. Coal rate per kw-hr. for month previous to starting turbine, 7.37 lbs. Coal rate per kw-hr. for month following installation, 5.7 lbs. This has been cut down to 4.4 lbs. for one month's average lately under better load conditions. Reduction in complete cost for year's turbine operation, seven months out of twelve, 13 percent. Do not have cost figured for shorter period than year. The turbine operates very satisfactorily on the exhaust of either engine or both, and governing is greatly improved on variable motor loads."

The above must evidently be treated relatively as the working conditions are those obtaining in a small central station with heavy standby losses. At a cotton mill, which had been operated by a 4.5 to 1 condensing engine, the coal consumption has been re-

duced to 1.057 lbs. per horse-power hour under normal running conditions, which is estimated to be an improvement of fully 20 percent over the previous rate of coal consumption.

A more comprehensive comparison of the improvement in

TABLE II—MONTHLY OPERATING COSTS

Month	Sept., 1908	Oct., 1909
Total kilowatt-hours	1 441 710	1 421 430
Fuel	$0.004650	$0.0030600
Boiler room labor	.000930	.0004850
Engine room labor	.000407	.0004830
Water	.000160	.0001609
Oil, waste, etc	.000029	.0000836
Repairs, steam	.000309	.0000879
Repairs, electrical	.000012	.0001408
General labor and repairs	.000013	.0002300
Sundry expenses and supplies	.000127	
Condensing apparatus repairs	.000000	.0000000
Total	$ .006637	$.0047312

power cost secured through the efficient use of low-pressure steam is included in the following analysis (Table II) of the records of a moderate sized central station. Months have been selected before and after the installation of the low-pressure turbine, in which the

TABLE III—CLASSIFICATION OF LOW-PRESSURE TURBINE INSTALLATIONS

Industry	Number of Low-Pressure Turbines
Iron and Steel Mills	10
Electric Railways	11
Machine Shops	8
Cotton Mills	7
Chemical and Electrolytic	4
Lighting Companies	5
Lumber Mills	2
Paper Mills	1
Mining	2
General Manufacturers	1
Total	60

average output was practically the same, but inasmuch as the addition of the low-pressure turbine has enlarged the rating of the plant, the comparison should have preferably been made with corresponding loading factors. It is, nevertheless, plain that there would have been a further reduction in operating cost, accentuating the value of the low-pressure turbine.

The fuel item has been reduced 34.2 percent. However, it must be remembered that the month including the low-pressure unit, was influenced by a relatively inferior load factor. There has also been a large decrease in the boiler room labor, viz., 47.8 percent. It seems plausible that the increased economy of the boiler room should exceed the percentage reduction in fuel when it is considered that the overload capacity of a combined unit is obtained with very small increase in water rate while a non-condensing engine rapidly falls off on overloads. Consequently, greater preparation for peak loads is required for the straight engine plant.

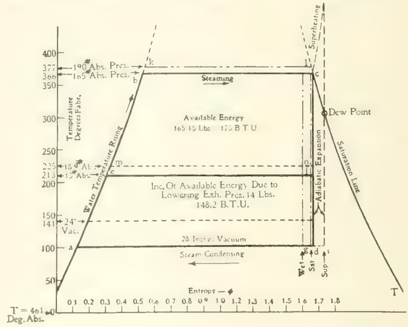

FIG. 18—TEMPERATURE ENTROPY DIAGRAM

Illustrating the available energy in B.t.u. above and below atmosphere.

Regardless of the additional engine room machinery there has been no increase in engine room labor due to the simplicity of the turbine. If the labor were based on an equivalent rating, it would, no doubt, be another credit item. Taking into consideration the increased investment, a net improvement of 19.5 percent in overall cost has been obtained, regardless of the much lower load factor.

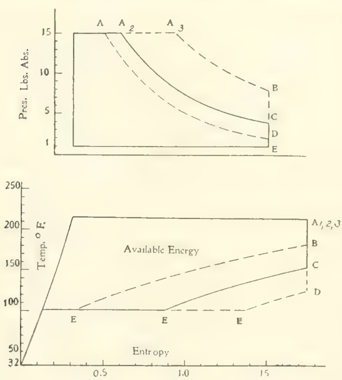

FIG. 19—LOSSES FROM INCOMPLETE EXPANSION

Shown by indicator and temperature-entropy diagrams.

CONCLUSION

The recognition accorded the low-pressure turbine is evidenced by the summary of installations, of one build of turbine, presented

in Table III, in which the machines have been classified according to the nature of the industry.

The choice of the governing systems employed in the above installations, has been determined largely by local conditions, which in the majority of instances, have dictated the use of the auxiliary live-steam admission valve. Electrical interlocking of turbine and engine, dispensing entirely with a turbine governor, is next in importance, while the synchronous motor scheme ranks third and the by-pass device fourth. The remaining systems have been used miscellaneously.

It is, of course, to be expected that as the number of installations increase, the above sequence may vary somewhat as new fields arise in the application of different governing methods. The order given, however, indicates their respective importance at the present time.

APPENDIX

EFFICIENCY RANGE—ENGINE VS. TURBINE

Without involving intricate technical quantities, the theoretical value of the adiabatic expansion of steam between various limits may be understood from the temperature entropy diagram, Fig. 18. These two factors constitute the heat content of steam, analogous to weight and distance or pressure and volume in work. From standard steam tables, the line *ak*, Fig. 18, representing the heat of the liquid and *ct*, the saturation line, may be obtained. The other heat actions are shown; thus, steaming along *bc* obviously at constant temperature; *cd* adiabatic expansion without giving up or receiving heat from an external source (which may be satisfied only by a vertical ordinate); and finally, *da* exhausting at constant temperature. Thus a heat cycle is established of a value fully equivalent to that of the indicator card of the reciprocating engine. By including the line *ef* corresponding to the temperature of steam at atmospheric pressure, division of the energy available under ordinary conditions above and below atmosphere is forcibly shown, thus emphasizing the energy in steam at low pressures. Due to the ability of the turbine to carry out economically the expansion of the steam to the lower practical limit, it has rapidly exceeded the reciprocating engine in efficiency, since in order to accomplish the same results, the engine would have to be of unreasonable proportions and encumbered by heavy friction and cyclical condensation losses. A visual conception of the loss from incomplete expansion may be had from Fig. 19, in which the work theoretically performed in the low-pressure cylinder is represented by both indicator card and temperature-entropy diagrams.

In the higher ranges, as for instance from 150 lbs. to atmospheric pressure, the expansion may be readily carried out in the steam engine, due to small volumes, and similarly in the turbine. In the former the density of the steam offers but little resistance to the motion of the engine parts, while with the turbine the "windage" factor and leakage is sensibly increased, resulting in engine efficiencies slightly exceeding in non-condensing operation. But the improvement in recent turbine design has greatly reduced the difference in non-condensing performance of the two types. As the fuel expense is not necessarily of great moment in most non-condensing plants, the turbine may easily overbalance the better steam consumption of the engine by reason of its mechanical superiority.

GROUNDED AND UNGROUNDED TRANSMISSION CIRCUITS*

J. S. PECK

[This is the eighth of the series of articles on the general subject of continuity of service in transmission systems, dealing particularly with static stresses and line troubles, and the proper protection of transmission systems from such troubles.]

THE question of grounding or not grounding the neutral and of the best method of connecting transformers is one of great importance, and it is the object of this article to point out some of the conditions, both normal and abnormal, which arise with different systems of connections with and without grounded neutral.

By the grounding of the neutral point of a transmission system it is sought:—

I—To limit the strain from line wires to ground.

II—To limit the strain between high-tension and low-tension windings of the transformers, also between high-tension windings and iron core.

There are a number of different ways of connecting single transformers for transmission work:—

Single-phase, two-phase, three-phase-delta, three-phase T, three-phase V, two-phase—three-phase, three-phase-star, three-phase-star-and-delta, while three-phase transformers of either the shell or core type may have their windings connected delta-delta, star-star, delta-star, or star-delta.

Consider first the case of a single-phase transformer ungrounded, with high-tension and low-tension voltage taken for convenience as 10 000 and 1 000 respectively, as shown in Fig. 1. There is evidently a maximum strain of 10 000 volts from one high-tension line wire to the other. If the circuits are insulated and symmetrical there will be a strain of 5 000 volts from each line wire to ground, and from each extremity of the high-tension winding to the low-tension winding and to the iron core.

If, however, the circuits are not symmetrical, the full strain will not be equally divided, and, if in an extreme case one high-tension wire is grounded, there will be a strain of 10 000 volts from the other line wire to ground; similarly, if one extremity of the

*Revised by the author from a discussion of a paper by Mr. F. O. Blackwell, read before the American Institute of Electrical Engineers, July, 1903.

high-tension winding be connected to the low-tension winding or to the core, there will be a strain of 10 000 volts from the other extremity of the high-tension winding to the low-tension winding or to the core. The actual strain between adjacent high-tension and low-tension windings is equal to the high-tension voltage plus or minus the low-tension voltage, depending upon the arrangement and connection of the coils.*

If the middle or neutral points of the high-tension and low-tension windings are grounded, the iron core being also grounded, as shown in Fig. 2, then as long as the circuits are in balance the voltage strains will be the same as with the windings ungrounded and balanced; but in case of a ground on either high-tension or low-tension line, or in case of a connection between high-tension and low-tension windings, a portion of the windings will be short-circuited. This will, in general, blow fuses or circuit breakers, thus cutting the transformer out of service; or the voltage of the system will be lowered to such an extent as to call attention to the trouble.

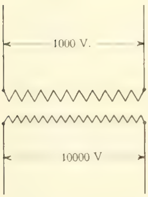

FIG. 1—SINGLE-PHASE, 1 000 TO 10 000 VOLTS. Maximum strain to ground, 10 000 volts.

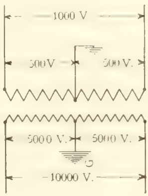

FIG. 2—SINGLE-PHASE, GROUNDED NEUTRALS, 1 000/10 000 VOLTS. Maximum strain to ground, 5 000 volts.

Thus, on a single-phase transmission system, the grounding of the neutral point of primary and secondary windings will limit the strain from line to ground, and from either extremity of high-tension to low-tension and iron to approximately one-half of the normal voltage of the system. If the neutral of only one winding is grounded, the strain from this winding to ground will be limited to approximately one-half of its normal voltage, but the strain from the ungrounded winding to ground, to iron and to the grounded winding will not be thus limited.

In considering other systems, the voltage strains between primary and secondary will not be mentioned, as these strains are easily calculated when the voltage on the transformers and the strain to ground is known. A short-circuit on a system will be assumed to cut out the transformers.

*See article by Mr. C. Fortescue on "Electrostatic Stresses and Ground Connections" in the JOURNAL for March, 1910, p. 266.

TWO-PHASE—FOUR-WIRE SYSTEM

The two-phase—four-wire system is practically a double single-phase system, and the conditions for grounded and ungrounded neutral will be the same as for single-phase.

TWO-PHASE—THREE-WIRE SYSTEM

The voltage across the two outside wires is 1.4 times that between the middle and either outside wire. The connections and voltages for 1 000 to 10 000 volt transformers are shown in Fig. 3.

A ground on the middle wire will give a strain of 10 000 volts between each outside wire and ground, while a ground upon an outside wire will give a strain of 10 000 volts from middle wire to ground, and of 14 000 volts from the other outside wire to ground.

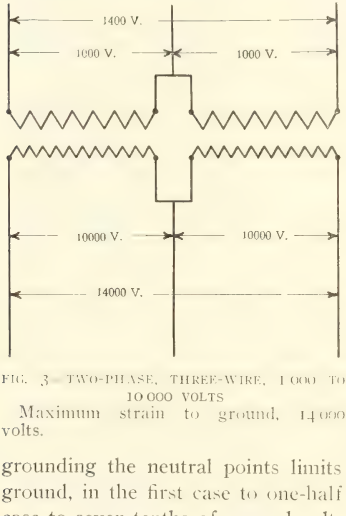

FIG. 3—TWO-PHASE, THREE-WIRE, 1 000 TO 10 000 VOLTS

Maximum strain to ground, 14 000 volts.

The neutral point for this system may be obtained from the middle point of an auto-transformer connected across the transformer windings. In this case, a ground upon any line will cause a short-circuit on the transformers, thus limiting the strain to ground to approximately seven-tenths of normal line voltage.

Thus, with a two-phase - four-wire or a two-phase — three - wire system, grounding the neutral points limits the strain from line wires to ground, in the first case to one-half normal voltage; in the second case to seven-tenths of normal voltage.

In general, the method of obtaining the neutral point by means of auto-transformers is not feasible on high-tension systems on account of the comparatively great cost of an auto-transformer wound for the high-tension voltage, and it will not be further considered in this discussion.

THREE-PHASE, DELTA SYSTEM

With the three-phase, delta system, shown in Fig. 4, the strain from any line wire to ground is, with the system in perfect balance,

58 percent of the line voltage. In case of a ground on any line wire, the two remaining wires are raised to full line potential above the ground. With this connection one transformer may be cut out, leaving two connected in V, and the above conditions will not be changed.

THREE-PHASE T AND TWO-PHASE—THREE-PHASE SYSTEM

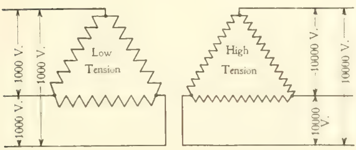

FIG. 4—THREE-PHASE DELTA CONNECTION, 1 000/10 000 VOLTS
Maximum strain to ground, 10 000 volts.

With either the T or two-phase — three-phase connection the voltage strains with ungrounded neutral are the same as for the delta system. The neutral point may, however, be obtained from the teaser winding, as shown in Figs. 5 and 6, in which case a ground upon any line wire will short-circuit portions of the windings.

With the three-phase T and two-phase—three-phase connection, the grounding of the neutral limits the voltage between line and ground to 58 percent of normal.

STAR SYSTEM

With transformers connected in star the conditions are very similar to those where two transformers are connected with pri-

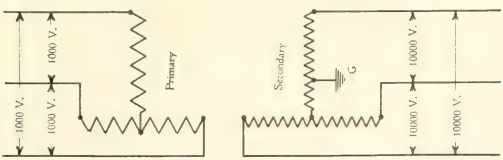

FIG. 5—THREE-PHASE T SYSTEM, 1 000/10 000 VOLTS; NEUTRAL GROUNDED
Maximum strain to ground, 5 800 volts.

mary windings in series and also the secondaries in series. Fig. 7 shows such a series combination, neutral not grounded. The total line voltage will divide with approximate equality between the two transformers. Between line wires and ground there will exist the same strain as with a single transformer, having the same total voltage; but if one transformer be short-circuited, the full volt-

age will be concentrated upon the other transformer so that the internal voltage strains on this transformer will be doubled and its iron loss greatly increased, though the strain from line wires to ground may be the same as before.

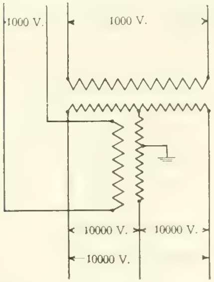

FIG. 6 — TWO-PHASE — THREE-PHASE SYSTEM, 1 000/10 000 VOLTS; NEUTRAL GROUNDED
Maximum strain to ground, 5 800 volts (approx.).

If the series connection between the two transformers be grounded and a ground occur on either line wire, as indicated in Fig. 8, the transformer connected to this wire will take the full voltage of the circuit and the ungrounded wire will be raised to full line voltage above ground. Unless the leakage current of the transformer working at double voltage is sufficient to open the circuit, the transformer may continue to operate indefinitely under the above conditions, provided it does not break down, due to excessive heating or to the double voltage strains to which it is subjected.

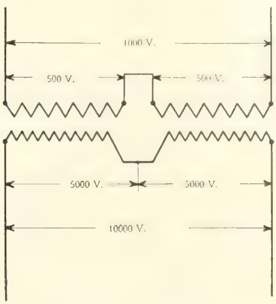

FIG. 7—TWO TRANSFORMERS, 1 000 TO 10 000 VOLTS; PRIMARIES AND SECONDARIES IN SERIES; NEUTRAL UNGROUNDED
Each unit takes approximately one-half line voltage.

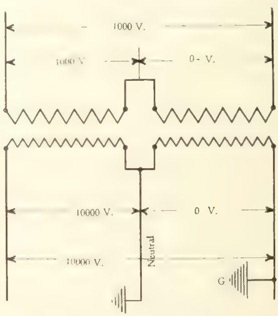

FIG. 8 -TWO TRANSFORMERS, PRIMARIES AND SECONDARIES IN SERIES; NEUTRAL GROUNDED
Ground on outside line wire short-circuits adjacent transformer and gives double voltage on other unit. Full voltage strain to ground.

A star-connected group of transformers is shown in Fig. 9, with the neutral point of the primary and of the secondary, and also that of the generator, grounded. In this case no excessive

voltage can occur on any transformer, and the strain from any line wire to ground is limited to 58 percent of full line voltage, for a ground on any line or a short-circuit in any transformer will short-circuit the generator. The same system of connections but with the generator ground omitted is shown in Fig. 10. In this

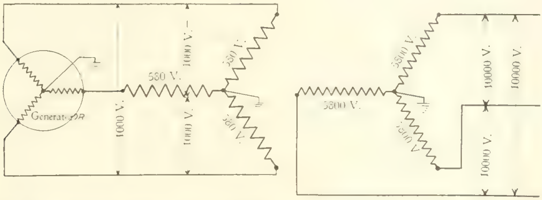

FIG. 9—THREE-PHASE STAR SYSTEM, LINE VOLTAGES 1 000 AND 10 000 VOLTS; TRANSFORMER VOLTAGES 580 AND 5 800 VOLTS

Grounds on generator and transformer neutrals. Maximum voltage per transformer, 5 800 volts; maximum strain to ground, 5 800 volts.

case a ground upon the primary or secondary line will short-circuit one transformer of the group and the two remaining ones will be operated at 73 percent above normal potential; also the strain between the ungrounded wires of the line will be that due to the full line voltage.

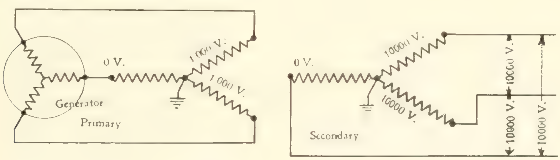

FIG. 10—THREE-PHASE STAR SYSTEM, PRIMARY AND SECONDARY NEUTRALS GROUNDED. LINE VOLTAGE, 1 000/10 000; NORMAL TRANSFORMER VOLTAGES, 580 AND 5 800

Ground on one line wire short-circuits one transformer, increases the voltage on the other two transformers 73 percent, and raises two line wires 10 000 volts above ground.

Thus, for a star connected system the grounding of the neutral points is of no value in limiting voltage strains on the system unless the neutral point of the generator is grounded; in fact, the grounding of the transformers instead of grounding the generator increases the chance for trouble, since a ground upon any line wire increases the voltage of two of the transformers by 73 percent.

STAR TO DELTA SYSTEM

A star to delta system is shown in Fig. 11. With this method of connection no excess voltage can be obtained on any transformer, and not more than full voltage strain to ground, provided the delta remains closed; but with the delta open at one point and a short-circuit on one transformer, as in Fig. 12, the voltage on the two remaining ones will be increased 73 percent and across two sides

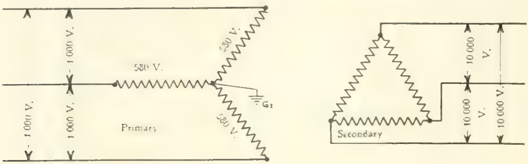

FIG 11—THREE-PHASE STAR TO DELTA SYSTEM, LINE VOLTAGES 1 000 AND 10 000 VOLTS; TRANSFORMER VOLTAGES, 580 AND 10 000 VOLTS

of the delta there will be *three times normal voltage*. Thus, on a 10 000 volt circuit, 30 000 volts may be obtained in case a transformer is short-circuited and cut out of the delta. This excess voltage across the two sides of the delta is due to the fact that a

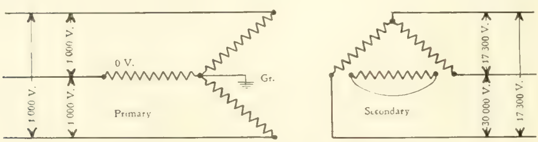

FIG. 12—THREE-PHASE STAR TO DELTA SYSTEM

Same as Fig. 11, except that the delta is opened and one transformer is short-circuited. The voltages of two transformers are thus increased 73 percent, and the voltage between two line wires is increased 200 percent.

short-circuit on the star changes the angular position of the voltages from 120 to 60 degrees, which in turn changes the angular position in the delta from 60 to 120 degrees.

DELTA TO STAR SYSTEM

With this system it is impossible to obtain voltages higher than normal upon any transformer or between any two line wires. A short-circuit in one transformer may, however, cut it out of the

delta but leave the star connection intact. In such a case the voltages will be as shown in Fig. 13. Two of the transformers operate at normal potential, with normal potential between two of the line wires, but with 58 percent of normal between the other wires.

STAR TO DELTA—RAISING: DELTA TO STAR—LOWERING

A transmission system is shown in Fig. 14 with raising transformers connected star to delta and lowering transformers con-

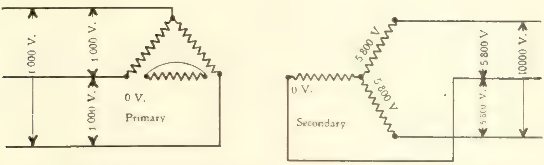

FIG. 13—THREE-PHASE DELTA TO STAR SYSTEM, LINE VOLTAGES 1 000 AND 10 000; TRANSFORMER VOLTAGES 1 000 AND 5 800

One transformer is short-circuited and cut out of the delta. Two transformers continue to operate at normal voltage, giving 10 000 volts across two line wires, 5 800 volts across the others.

nected delta to star. The voltages obtained across transformers and across line wires are shown. The neutral points of the low-tension windings of both raising and lowering transformers are grounded.

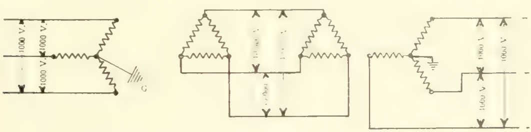

FIG. 14—STAR-DELTA RAISING, DELTA-STAR LOWERING SYSTEM; NEUTRAL OF RAISING AND LOWERING TRANSFORMERS GROUNDED. LINE VOLTAGES 1 000 TO 10 000 TO 1 000 VOLTS; TRANSFORMER VOLTAGES 580 TO 10 000 TO 580 VOLTS

Fig. 15 shows the voltages which will be obtained with a ground on one low-tension lead which short-circuits one transformer. The high-tension side of this transformer is cut out of the delta. The voltage across the other transformer is increased 73 percent and the phase relation changed from 120 to 60 degrees, the voltages being as shown in Fig. 12. On the lowering delta, three times normal voltage is impressed on one transformer and 73 percent above normal voltage on the other two. The voltages obtainable across the star on the lowering transformers are readily

understood from the figure. It will be noted that across one phase there is normal voltage and across the other two phases 2.7 times normal voltage. A transformer subjected to three times normal voltage would take so large a current as to blow fuses, and with silicon steel transformers this result would probably follow the application of 73 percent excess voltage.

With this system of connections, grounding the neutral point

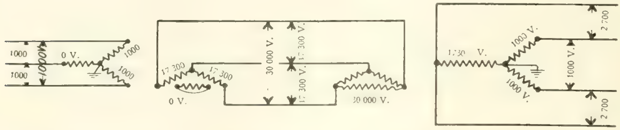

FIG. 15—SAME AS FIG. 14, EXCEPT THAT ONE RAISING TRANSFORMER IS SHORT-CIRCUITED AND CUT OUT OF THE DELTA

Voltages on raising transformers respectively 73 percent above normal and zero. Voltages, on lowering transformers respectively 73 percent and 200 percent above normal. Voltages on secondary of lowering transformers respectively normal and 170 percent above normal.

of the star without a ground upon the neutral point of the generator is of no use in preventing unequal and excessive strains on the transformers and from line wires to ground. Should the delta on the raising transformers be kept closed, it is obvious that a short-circuit on any raising transformer would short-circuit the generator, but the above condition is one which might occur where switches or fuses are placed inside the delta.

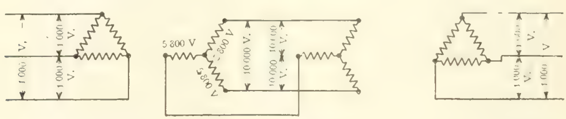

FIG. 16—DELTA-STAR RAISING, STAR-DELTA LOWERING SYSTEM; NEUTRALS NOT GROUNDED; LINE VOLTAGES 1 000 TO 10 000 TO 1 000; TRANSFORMER VOLTAGES 1 000 TO 5 800 AND 5 800 TO 1 000 VOLTS

DELTA TO STAR—RAISING: STAR TO DELTA—LOWERING

Fig. 16 shows voltages obtained under normal conditions with transformers connected delta to star and star to delta, with low-tension and high-tension voltages of 1 000 and 10 000 respectively.

Fig. 17 shows approximately the voltages and phase angles obtained when one raising transformer is short-circuited and cut out of the delta, but with the star connection intact. The voltages

obtained on the lowering delta will be approximately those shown. It will be noted that this delta has been twisted far out of its normal form, though the voltage on no transformer has been raised above normal and on the lowering transformer all voltages are below normal.

Fig. 18 shows the same connection, but with one transformer short-circuited and cut out of the delta. The voltage across one

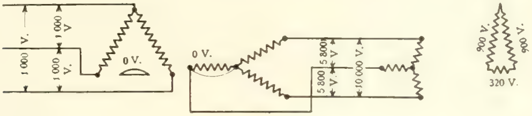

FIG. 17—SAME AS FIG. 16, EXCEPT THAT THE RAISING DELTA IS OPEN AND ONE TRANSFORMER IS SHORT-CIRCUITED

The voltage on the lowering transformers is less than normal. Note the extent to which the delta is distorted. If the neutral points of the raising and lowering transformers be grounded, this distortion cannot occur, as fuses will blow and open the circuit when the raising transformer is short-circuited.

of the remaining transformers is increased 73 percent, while that across the other remains normal. The voltage across the open side of the secondary delta is increased 165 percent above normal; that on one, 73 percent above normal and on the other it is normal.

If the neutral points of raising and lowering transformers are grounded the abnormal conditions shown in Figs. 17 and 18 cannot be obtained, for in this case, with the lowering delta closed, as in

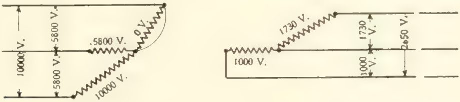

FIG. 18—SAME AS FIG. 17, EXCEPT THAT THE LOWERING DELTA IS OPEN AND ONE TRANSFORMER IS SHORT-CIRCUITED

The voltages on the raising transformers are respectively normal and zero (see Fig. 17). Those on the lowering transformers are respectively normal, 73 percent above normal, and zero. The voltages across the secondaries are respectively normal, 73 percent above normal, and 165 percent above normal.

Fig. 17, the fuses will be blown when a lowering transformer is short-circuited; and with the delta open, as shown in Fig. 18, a short-circuit in the lowering transformer will short-circuit the generator.

Some abnormal conditions which may be obtained from a few

of the possible combinations of transformers have been given above. These abnormal conditions are produced by combinations which are accidental or unusual; but it is the accidental or unusual condition which must be taken into consideration and guarded against, if trouble is to be avoided. Some of the conditions which are shown undoubtedly have occurred in practice and are possibly responsible for some of the troubles on high-voltage transmission systems.

Resonance—The abnormal voltages given above are those which are obtainable from the generator pressure through direct transformation. Another cause which may produce abnormal voltages is *resonance,* a condition which is particularly liable to occur when a high inductance, such as the winding of an idle transformer, is in series with a large capacity, such as that of a transmission line.

The foregoing examples are all based on the use of single-phase transformers. When three-phase shell type transformers are used, the conditions are practically identical with those given for single-phase transformers, but with a three-phase core type of construction the magnetic circuits of the three phases are so related that a short-circuit on one phase affects the whole magnetic circuit of the transformer; and, since all of the abnormal conditions already given are due primarily to a short-circuit on one phase, none of these conditions can occur with a three-phase core type transformer. Therefore connections may be used safely with this type of transformer which would be dangerous on a group of single-phase transformers or on a three-phase shell type transformer.

In addition to the combinations of single-phase transformers, there are the two-phase—three-phase, three-phase V, and three-phase T connections which may be used at either the raising or lowering ends. When used for raising transformers, these combinations will deliver their proper voltages to the line provided the proper voltages are impressed on their primary terminals, as it is impossible by short-circuiting one transformer to raise the voltage of the other.

When used as lowering transformers these combinations will supply to the secondary circuits voltages of proper amount and bearing the proper phase relation to each other, provided the voltages impressed on the primary side are of proper amount and proper phase relation to each other. If, however, the voltages applied to the primary are distorted, then the voltages delivered by the secondaries will be correspondingly distorted.

Grounded Neutrals—It will be noted that in many cases the

grounding of the neutral points of a transmission system limits the voltage strain to ground and the voltage which may be obtained across any transformer, and in such cases grounding would seem advisable. This is notable in the case of the star system with grounds on transformer and generator neutrals. There is, however, a danger arising from this grounding which should be carefully considered. In case of trouble on the circuits, current may flow through the ground to the neutral; in thus flowing it will naturally take the path of least resistance, so that if telephone or telegraph lines, which have normally low resistance to ground, parallel the transmission circuit, the current will flow along these wires, often with disastrous results to the circuits.

Two cases of trouble are particularly liable to give these conditions:—

I—Where the neutral points of the high-tension windings of raising and lowering transformers are grounded, the opening of one or two of the three transmission wires will cause currents to flow through the ground.

II—A high resistance ground on a transmission wire will partially short-circuit a transformer and cause current to flow through the ground to the neutral.

Some plants have been able to operate satisfactorily with grounded neutrals; with others this grounding has caused great disturbance on telephone circuits, and in one plant it is reported that the blowing of a fuse on one of the high-tension wires put the telephone systems in ten counties out of service.

With proper grounding of a system the trouble due to ground currents and telephone disturbances will be negligible. The grounds should be made where they will cause the least trouble and afford the best protection, which will usually be found to be in the low-tension side of the system, and it is now general practice to ground the low-voltage neutral points.

WINDING OF DYNAMO-ELECTRIC MACHINES--XII

CONNECTIONS OF ALTERNATING-CURRENT MACHINES

M. W. BARTMESS

THE DESIGN of a motor or generator winding depends for the most part on its application, the size and speed of the machine, and the voltage, frequency and number of phases of the circuit on which it is to be operated. Considerations of design and commercial manufacture also determine the number of slots

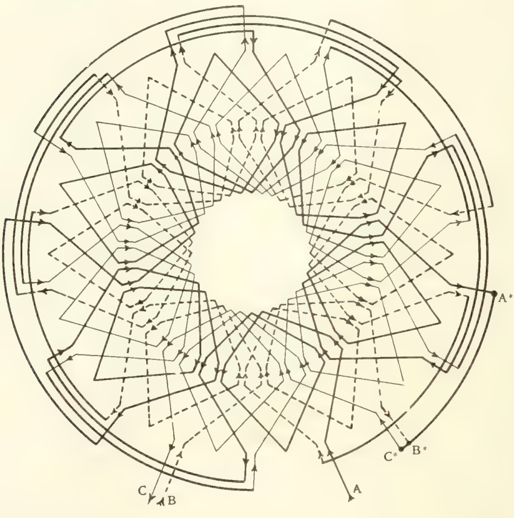

FIG. 134—GROUP WINDING, FULL PITCH, THREE-PHASE, SIX POLES, 36 SLOTS, 36 COILS, TWO COILS PER SLOT, TWO COILS PER GROUP, THROW *1-7*. CONNECTED IN SERIES STAR

and size and number of coils for a given type of machine. Having determined these features, the problem remains of connecting the coils into the proper number of series or parallel circuits.

GROUP WINDINGS

Group winding may be defined as that class wherein the total winding is divided into separate parts, composed of adjacent coils or conductors. The grouping is, in the case of lap and wave

windings, an arbitrary one, the coils being all similar and divided into groups solely by their connections. The number of coils per group may equal the number per pair of poles divided by the number of phases, or the number per pole divided by the number of phases, the latter method of grouping being so generally used on modern machines that it will be assumed throughout the present discussion, unless otherwise noted. Thus, in Fig. 134, a six-pole,

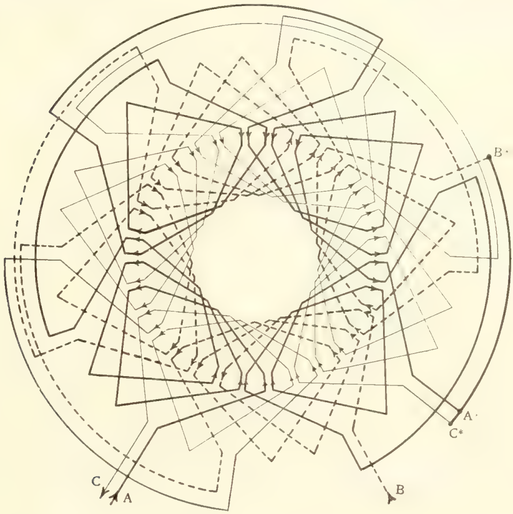

FIG. 135—GROUP WINDING, UNEQUAL GROUPS, THREE-PHASE, FOUR POLES, 30 SLOTS, 30 COILS, TWO COILS PER SLOT, TWO AND THREE COILS PER GROUP, THROW *1-8*, CONNECTED IN SERIES STAR

three-phase winding of 36 slots, the number of coils per group $=\frac{36}{6\times 3}=2$. Where the number of slots is not evenly divisible by the product of poles and phases, dissimilar groups must be employed. In such cases it is advisable to arrange the grouping so that all the phases have an equal number of coils, and if possible the grouping should be arranged symmetrically with respect to the core itself, as in Fig. 135. To prevent local currents, which may prove injurious, all circuits which are in parallel must have an equal number of coils and should be symmetrically arranged with respect to each other and to the other phases.

Although one turn coils only are shown in the accompanying diagrams, the same connections are applicable to windings having any number of conductors per coil. These conductors may all be in series, in which case there is one lead at each end of the coil, or the conductors may be divided into any number of equal parallels, in which case there are as many leads at the ends of the coil as there are parallel circuits. The leads at the beginning and end of the coil are connected in the same manner as indicated for the one turn per coil winding. For simplicity's sake the number of coils per

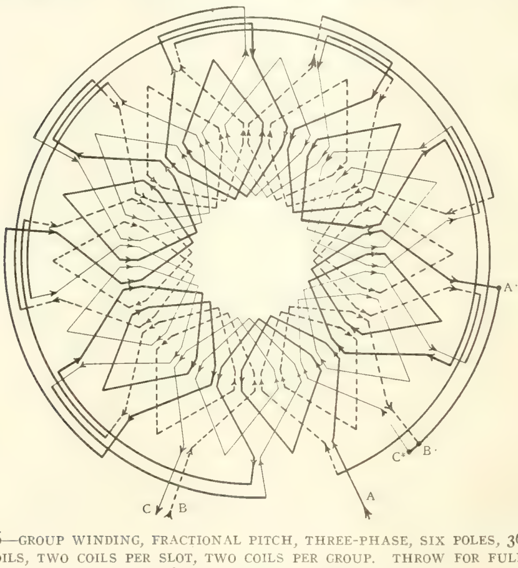

FIG. 136—GROUP WINDING, FRACTIONAL PITCH, THREE-PHASE, SIX POLES, 36 SLOTS, 36 COILS, TWO COILS PER SLOT, TWO COILS PER GROUP. THROW FOR FULL PITCH *1-7*, THROW AS WOUND *4-6*. CONNECTED IN SERIES STAR

group, and hence the total number of coils in the diagrams has been kept lower than is generally found in commercial machines.

FULL AND FRACTIONAL PITCH WINDINGS

The number of slots in the core, divided by the number of poles gives a value of the pole arc expressed in terms of the slots. A full pitch winding is one in which the effective span of the coils is equal to the pole arc, and a fractional pitch winding is one in which the

effective span of the coils is not equal to the pole arc, as shown in Fig. 136. For a two coil per slot, lap or wave winding, the effective span of the coil is equal to the actual span of the coil. In this case the full pitch winding is one where the coil lies in slots 1 and $\left(\frac{\text{total number of slots}}{\text{number of poles}} \text{ plus } 1\right)$. For a one coil per slot lap winding the effective span of the coil may be greater or less than its actual span. Fig. 137, *a* and *b* show two different coils, in each of which the effective span is the full pitch of 12 slots while the actual span in *a*, is only 11 slots and that in *b* is 13 slots. Needless to say, *a* is more generally used on account of the saving in copper and

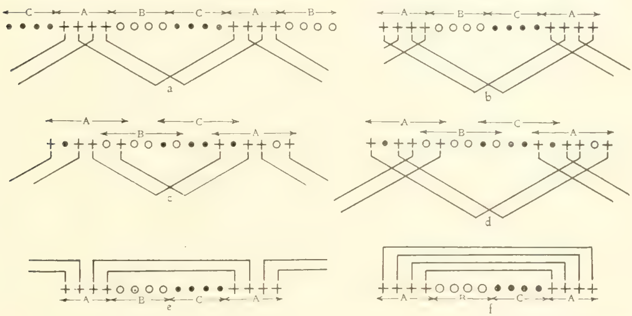

FIG. 137—SELECTION OF PITCH FOR ONE COIL PER SLOT WINDINGS

a—Full pitch, effective span 12, actual span 11, throw *1-12*.
b—Full Pitch, effective span 12, actual span 13, throw *1-14*.
c—Fractional pitch, effective span 10, actual span 9, throw *1-10*.
d—Fractional pitch, effective span 10, actual span 15, throw *1-16*.
e—Concentric group, full pitch, effective span 12, actual span 9 and 11, throw *1-11*.
f—Concentric group, full pitch, consequent poles, effective span 12, actual span 9, 11, 13 and 15, throw *1-13*.

space for end connections. A coil with a span either less or greater than that shown would result in a fractional pitch, as in *c* and *d*.

Representative cases of concentric group windings are shown in Fig. 137, *e* and *f*, *e* representing a three-bank winding, in which the number of coils per group equals the total number of coils per phase divided by the number of poles, while *f* represents a two-bank winding of the consequent pole type in which the number of coils per group equals the total number of coils per phase divided by the number of pairs of poles. Neither of these types can be conveniently wound with a fractional pitch, especially with formed coils.

Where dissimilar groups are employed, i. e., where the number of slots is not evenly divisible by the product of phases and poles, the full pitch is frequently not a unit and hence a fractional pitch is necessary. Thus, in Fig. 135, full pitch covers a span of 7.5 slots and the nearest lower even pitch gives a throw of *1-8*.

In general, fractional pitch affects the performance of the apparatus similarly to a reduced number of turns in the winding, but not in the same proportion. In a generator this reduces the voltage

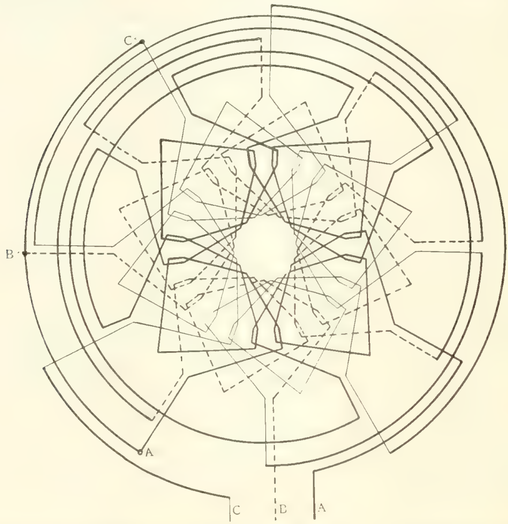

FIG. 138—GROUP WINDING, FULL PITCH, THREE-PHASE, FOUR POLES, 24 SLOTS, 24 COILS, TWO COILS PER SLOT, TWO COILS PER GROUP,, THROW *1-7*. CONNECTED IN SERIES STAR

Connected for alternate voltages, so that when connected in parallel, the groups in each parallel circuit will be distributed around the core.

of the machine. In an induction motor the maximum available torque is increased but the densities in the magnetic circuit are also increased with a resulting reduction of power-factor. For either motor or generator, considerable copper may thus be saved in the coil ends and a standard frame may frequently be used for special purposes.

THE SIMPLIFIED DIAGRAM

By referring to Figs. 134 to 141, it is evident that for all com-

binations the number of diagrams necessary would be unlimited. A simplified diagram may be employed which will not only reduce the required number of such diagrams but will also minimize the labor in tracing out the connections. Thus it will be seen that the diagram in Fig. 142, will satisfy all requirements for connections of groups for the diagrams in Figs. 138 or 139. In addition to this it will apply for any similarly connected three-phase, four-pole, series star lap-winding, irrespective of the number of coils per group (provided

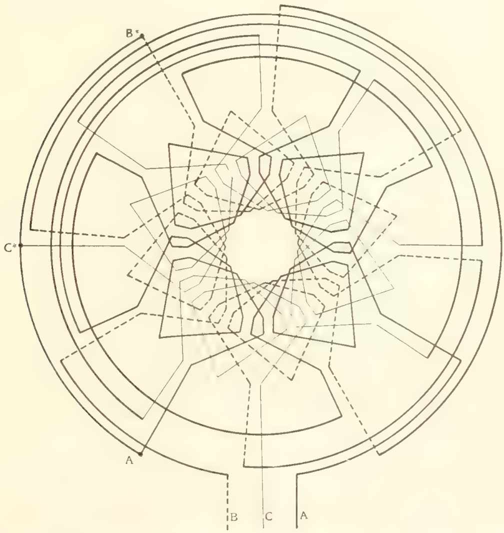

FIG. 139—GROUP WINDING, FULL PITCH, THREE-PHASE, FOUR POLES, 48 SLOTS, 24 COILS, ONE COIL PER SLOT, TWO COILS PER GROUP, THROW *1-12*.
Connected same as Fig. 138.

the groups are regular), or of the throw of the coils, that is, whether the winding is full or fractional pitch. This information for the throw of the coil and the number of coils per group may be carried on the same specification with the remaining winding constants. The groups are formed by connecting the required number of coils together, the end of the first coil to the beginning of the second, etc., the beginning of the first coil and the end of the last coil in the group forming the beginning and end of the group. Such diagrams may be made for any number of phases, poles or possible parallel circuits,

and for any desired method of connection of the groups. In case the coils per group are irregular or unbalanced it is advisable to have a special diagram giving the number of coils in each group, their location and any other information necessary.

It is obvious that if a winding gives satisfactory operation on a certain voltage, a similar winding of one-half the number of series conductors, but of double the current carrying capacity, will give satisfactory operation on one-half the voltage. This latter condition

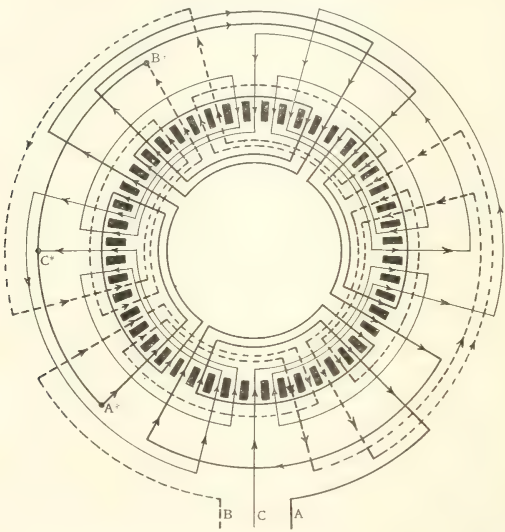

FIG. 140—CONCENTRIC GROUP WINDING, FULL PITCH, THREE-PHASE, FOUR POLES, 48 SLOTS, 24 COILS, ONE COIL PER SLOT, TWO COILS PER GROUP, THROW *1-11*. CONNECTED IN SERIES STAR

may be obtained by paralleling the groups, as in Figs. 143 and 144, or where this is impossible by paralleling the series conductors in the slots. For example, if the full voltage connection of a 14 pole motor corresponds to the parallel connection the only method to change to half voltage would be to change the winding itself since 14 poles does not permit of a four-parallel connection. Again an irregularity of coils per group will at times prevent doubling the parallel circuits where otherwise this might be possible.

When it is desired to use one winding for either full or half voltage, the winding, if possible, is laid out for equally satisfactory operation on either connection, and for the minimum amount of labor required to connect from one to the other. This is exemplified by Figs. 138, 139, 142 and 143. It is evident that any eccentricity of the rotor with respect to the stator will affect equally the circuits which are in parallel. In contrast to this are Figs. 134, 135 and 136,

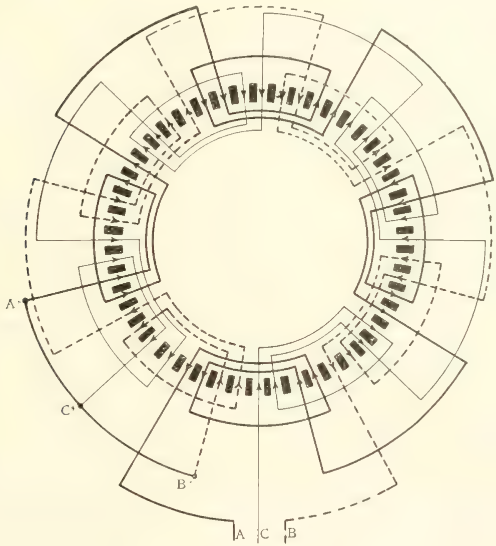

FIG. 141—CONCENTRIC GROUP WINDING, CONSEQUENT POLE TYPE, FULL PITCH, THREE-PHASE, EIGHT POLES, 48 SLOTS, 24 COILS, ONE COIL PER SLOT, TWO COILS PER GROUP, THROW *1-7*. CONNECTED IN SERIES STAR

which, if connected in parallel, would place the parallel circuits on opposite sides of the machine and any eccentricity of the two elements will mean an unbalancing of the current in the two halves of the winding.

A simple method for obtaining the proper polarity of the groups is indicated in Figs. 142 and 143 for three-phase and Fig. 144 for two-phase winding. In a three-phase star winding by traveling from each of the three leads to the star points, the direction of travel is

reversed in adjacent groups. In a two-phase diagram the only necessary precaution in determining the proper polarity is to remember that adjacent groups of the same phase are reversed. By marking the groups *A, B, C,* etc., and indicating the direction of travel, it is a simple matter to connect them in the proper direction. Additional index marks may be given on the diagram to aid in connecting the winding, by marking those group ends which are joined by the same connector, with the same numeral.

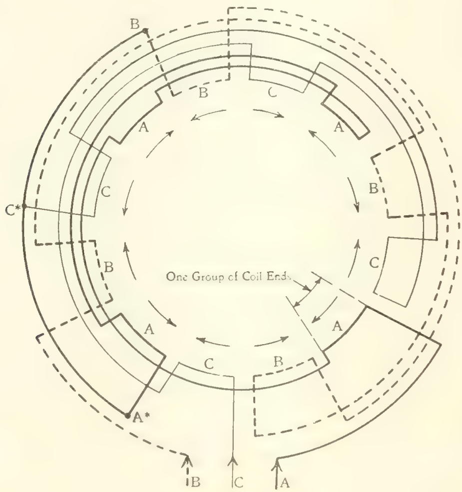

FIG. 142—SIMPLIFIED DIAGRAM, THREE-PHASE, FOUR POLES. GROUPS CONNECTED IN SERIES STAR

This is a general diagram, of which Figs. 138 and 139 are particular examples, and is applicable for any number of coils per group, and any pitch of coils.

Any star diagram can be readily changed into a corresponding delta diagram by opening up the star points and connecting the inner end of phase *A* to the outer end of phase *B* or *C,* the inner end of phase *B* to the outer end of phase *C* or *A*, and the inner end of phase *C* to the outer end of phase *A* or *B*. If the star diagram is not symmetrical with respects to the three phases it is never advisable to change over to delta.

WAVE WINDINGS

In a wave winding, correspondingly placed conductors under adjacent poles are connected in series, the circuit proceeding from pole to pole one or more times around the core, and not forward and back upon itself as in a lap winding. The circuits are then interconnected in such a manner as to give the requisite phase relations. The total number of these circuits must be a multiple of the number of phases and is ordinarily twice the number of phases. Due to certain limitations, this type of winding is not used to as great an extent

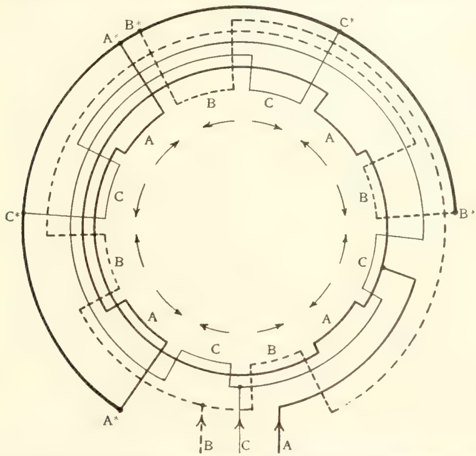

FIG. 143—SIMPLIFIED DIAGRAM, THREE-PHASE, FOUR POLES. GROUPS CONNECTED IN TWO PARALLEL STAR

This is the same winding as shown in Fig. 142, connected in parallel.

as the lap or the concentric windings. Its use on small motors is limited to phase-wound secondaries. Since a two-phase secondary would require four collector rings, or if connected for a three-wire system, would overload one of the rings, while a three-phase winding requires but three rings, the latter only is general for such applications.

The number of slots for this type of winding (plus or minus one) is so chosen as to be divisible by the number of pairs of poles or preferably by the number of poles. If plus one, it is said to be a progressive winding, since after traveling once around the circuit it returns to the starting slot plus one. If minus one, it is said to be

retrogressive since the circuit returns the winding to the starting slot minus one. With this arrangement it is impossible to balance the phases exactly, but the effective unbalancing is small with a large number of slots. Since an unbalanced three-phase winding is less objectionable than a two-phase winding, the scheme is used chiefly for the former. Again, since an unbalanced winding is less detrimental in a secondary circuit than in a primary, the principal application of this type of winding has been in secondary circuits.

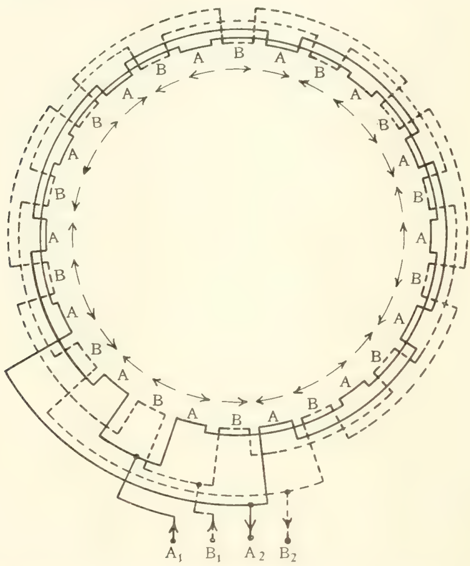

FIG. 144—SIMPLIFIED DIAGRAM, TWO-PHASE, 14 POLES. GROUPS CONNECTED IN TWO PARALLELS

Fig. 145 represents a two conductor per slot winding, such as a bar and end conductor type but is equally applicable to strap or wire wound coils of two or more series turns per coil, in which case the connector on the rear end of the coil takes care of itself and the front end is connected in a manner similar to the sketches. There are several methods of connecting up the three-phases depending on the desired voltage. The principal connection is indicated on Fig.

145. By connecting the end of each series circuit to the beginning of the next and taking off leads at the point of connection of series *1-2, 3-4, 5-6,* instead of the connections between the series shown in Fig. 145, a connection is obtained for one-half voltage. An 86 percent voltage tap in terms of the connections shown in Fig. 145 is secured by connecting the end of series *2* to the beginning of series *3*, the end of series *4* to the beginning of series *5*, the end of series *6* to the beginning of series *1*. To connect in star join the ends of

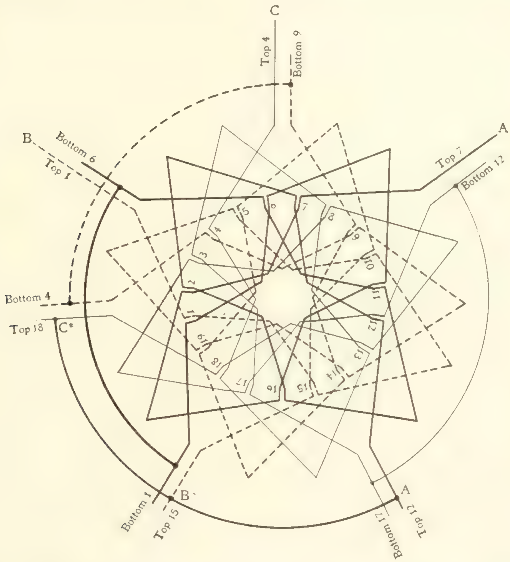

FIG. 145—WAVE WINDING, THREE-PHASE, FOUR POLES, 19 SLOTS, 19 COILS, TWO COILS PER SLOT, THROW *1-6,* UNBALANCED PHASES. CONNECTED IN SERIES STAR

First Series begins bottom slot *6*, ends top slot *12*.
Second Series begins bottom slot *17*, ends top slot *4*.
Third Series begins bottom slot *9*, ends top slot *15*.
Fourth Series begins bottom slot *1*, ends top slot *7*.
Fifth Series begins bottom slot *12*, ends top slot *18*.
Sixth Series begins bottom slot *4*, ends top slot *1*.

series *1*, series *3*, and series *5*, and take off leads at the beginning of series *6*, series *2*, and series *4*. Since this connection reduces the voltage without increasing the cross section of the copper the winding will be less efficient on account of higher copper loss for the

same output. This is also true of the 50 percent voltage connection, since for the same output the current density in the windings is 15 percent greater than for the full voltage connection.

It is possible, by choosing a number of slots which is divisible by the product of the number of phases by the number of poles, to lay out a winding which is balanced. For such a winding the circuit after passing once around the armature, returns to the starting slot. It is then only necessary to supply a special connector to join it to the conductor in the starting slot plus or minus one. This winding

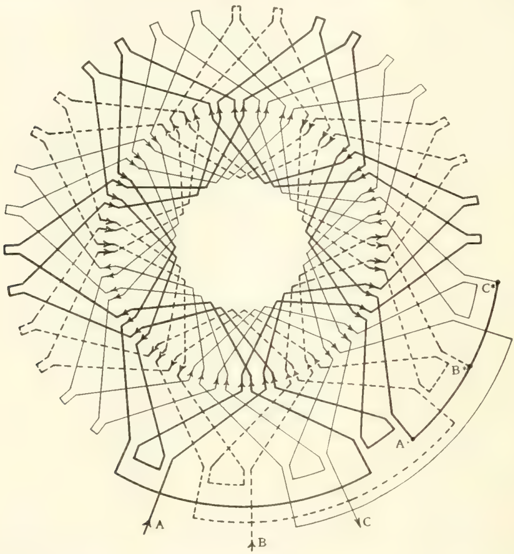

FIG. 146—WAVE WINDING, THREE-PHASE, SIX POLES, 36 SLOTS, 36 COILS, TWO COILS PER SLOT, THROW *1-7*. CONNECTED IN SERIES STAR

thus embodies the best features of both types as, for example, an electrical balance, and a minimum number of special connections, which means a very compact and easily-assembled winding. By inspecting Fig. 146, it is evident that the number of special connections is comparatively small with respect to the number of coils, and this feature is more pronounced as the number of poles is increased. Hence for a winding for a large number of poles, 12 to 40, the number of special connections becomes insignificant.

THE JOURNAL QUESTION BOX

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Address all questions to The Journal Question Box, care of The Electric Journal Box 911, Pittsburgh, Pa.

543—Distributing Systems for Single-Phase Railways—Please outline, or indicate where I may find, a method of calculating distributing systems for single-phase railways, similar to the method given by Mr. F. E. Wynne for direct-current railways in the series on Railway Engineering, in the JOURNAL for October, 1908, p. 580. F. S.

The general method is the same as outlined in the article mentioned in the question. It is not permissible to allow so great a percentage drop in contact line (trolley) voltage with single-phase current as with direct-current, because the drops in transformers, transmission line and contact line add together to give the total drop between generators and rolling stock without any counterbalancing effect such as is obtained through the compounding of the rotary converters used in direct-current sub-stations. If a single-phase trolley line is fed from the power-station direct without intermediate transformers and transmission line a maximum drop of 25 to 35 percent of the power house voltage is permissible. If the trolley is fed through transformer stations the maximum drop from transformer stations to rolling stock should not exceed 15 or 20 percent. In single-phase installations it is rarely necessary to use feeders paralleling the trolley. Since high voltages are used the trolley should always be of the catenary type. A few constants will be of assistance in calculating single-phase line drops. For No. 4/0 trolley, 22 feet above 70 lbs. single track, with 25 cycles the drop per mile per 100 amperes is 55.9 volts and the power-factor is 54.2 percent; for No. 3/0 trolley the unit drop is 60.3 volts and the power-factor is 61.5 percent. With No. 4/0 trolley and 100 lbs. single track the unit drop is 55.3 volts and the power-factor is 52.4 percent; with No. 4/0 trolley and 100 lbs. double track the unit drop is 31.1 volts and the power-factor is 49.9 percent. By applying the power-factor, the total unit drop in any case may be separated into its ohmic and inductive components, the ohmic component alone being used in calculations for loss in the trolley and track circuit. As an example consider the train sheet given on p. 586 of the article referred to in the question. Assume the interurban section to be fed direct from the power house at 11 000 volts; car at starting to take 33 amperes and car running to take 15 amperes; single No. 3/0 trolley and 70 lbs. single track; also drop per mile per 100 amperes to be 60.3 volts. At about 2.22 P. M. with two cars meeting near *E*, two at sub-station No. 2 and two at *H*, the drop from power house to *H* will be 1070 volts estimated as follows:—*H* to sub-station No. 2 (15 miles) 48 amperes; sub-station No. 2 to stub near *E* (5 miles) 96 amperes; sub-station near *E* to power house (4 miles) 144 amperes; total drop $= [(15 \times 0.48) + (5 \times 0.96) + (4 \times 1.44)] \times 60.3 = 1070$ volts $= 9.75$ percent. Other cases may be solved in a similar manner, either assuming the size of trolley and estimating the drop or assuming the drop and trolley size and figuring the distance between sub-stations.

F. E. W.

544—Zerener Electric Blowpipe—Please advise how the "Zerener" electric blowpipe is constructed. One is desired which will carry a current of 100 amperes and be automatic in action. Would a

rheostat constructed of carbon be practicable? If so, what size of carbon would be required to maintain a current of 150 amperes, without destroying the service fuses? J. R.

The Zerener blow pipe is not used in this country to any extent, if at all, and while we have consulted several authorities in electrical matters as to its use abroad, none is able to advise concerning it. The same work may be accomplished by means of the Benardos or the Slavinanoff process and without the complicated apparatus required apparently in the Zerener blow pipe, so that we suggest either of these processes to be followed instead. For articles on Oxy-Acetelene, Benardos (arc) and Thompson (incandescent) welding processes see The Seven-Year Topical Index of the JOURNAL. C. B. A.

545—National Board of Fire Underwriters—Can you tell me the address of the National Board of Fire Underwriters or what process is necessary to bring articles of manufacture before the board for approval. G. I. M.

Any fitting such as is used in connection with fire systems, fire protection, or the use of which may possibly constitute a fire hazard, may be brought before the National Board of Fire Underwriters for approval by submitting sample to the Underwriters' Laboratories, 207 East Ohio street, Chicago, Ill., and paying the necessary fee for examination. The Underwriters' Laboratories will make examination and test, and will report to the proper committee of the National Board, who will take final action in regard to approval of the device in question. C. E. S.

546—Centrifugal Pump Calculations—A pump direct-coupled to a two hp, 1800 r.p.m. induction motor, having one and one-half inch suction and delivery pipes, would pump about 60 gallons per minute for two to five minutes, then lose its vacuum, the time varying with the height of water in the tank. The distance from the surface of the water in the well to the center of the pump was 14 feet and from pump to tank surface 25 feet or total, 39 feet. The runner is six inches in diameter and the case, ten inches clear inside diameter. We have been informed that we need an eight inch runner. Is this correct? Please advise method of calculating size of pump and runner in a given case. V. J. C.

The pump probably loses its vacuum for one of two reasons; if there is any appreciable air leakage in the suction line the infiltration of air may accumulate at some particular point, more especially a bend or crest in the line, establishing an air pocket and destroying the vacuum or, if the height of the water became greater than the elevating power of the pump a churning of the water would take place , thus heating the stagnant water by friction, and the vacuum which it will then pull will be determined by the steam tension corresponding to the water temperature. For example, the theoretical vacuum which may be created by the pump, without regarding the presence of any air, will be approximately as follows:—

Water Temp.	Theoretical Vacuum in Inches. (30″ baro.)	Corres. Water Lift no deduction for friction head.
80	29″	33.2
102	28	32
126	26	29.7
150	22.5	25.7

Considerable deduction must be made in the theoretical lift for friction, depending on the velocity and connections. The diameter of the runner is obtained from the formulae $V = 0.9 \times \sqrt{2gh}$ where V is the peripheral velocity, $2g = 64.4$ and h = the delivery head. The constant may vary for .8 to 1.2 depending upon the design of the pump. Notes on pump design may be found in Kent's Mechanical Engineers' Handbook. E. D. D.

547—Induction on Telephone Line Paralleling Transmission Sys-

tem—We have a circuit which parallels a grounded telephone line and, of course, there is noise on the telephone. Fig. 547 (a) represents the relative positions, etc., of the two circuits. We have tried a metallic return circuit, removing the ground at *A*, and grounding the second line at *B*; also, transposing our line; also making a complete metallic circuit of the section *AB* of the telephone line and connecting it through a repeating coil to the grounded part, a scheme suggested by the local telephone man. Any help which you may be able to give will be much appreciated. J. B. G.

The static induction on a telephone line from a high-tension line carried on the same poles may result in a very considerable potential on a perfectly insulated telephone line, and hence, to produce perfect quiet it would be necessary to insulate the telephone line like a high-tension line and insulate the telephone instruments and parties using them in the same manner. It is advisable to insulate the instruments and persons

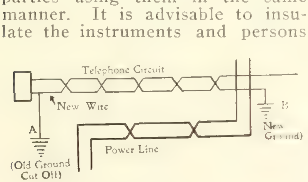

Fig. 547 (a)

using them to avoid accident in case of a failure of the high-tension construction, but it is not practicable to insulate the telephone line on a high-tension basis. While the potentials may be considerable, the current which would flow were the telephone line grounded would be small. These small currents flowing through the receiver are sufficient to destroy all possibility of carrying on a conversation over the line. It is necessary, therefore, inasmuch as there is a leak on one side of the line, to produce an equal leak on the other. In order to do this it is advisable to place a permanent leak on each side of the line sufficiently heavy to far outweight the insulator leak, etc. This may be a non-inductive resistance of from 5 000 to 10 000 ohms, for a magneto line, and should be placed near the instrument. All grounds must be removed from the telephone. This may be done, if grounded bells are used, by connecting the bell ground through a switch which is opened by the raising of the receiver hook. In the case of the grounded line the same would apply but in addition a repeating coil should be placed at the far end of the exposure and the exposed portion of the line entirely insulated from the ground, except as mentioned above. For the ground resistance, carbon or graphite rods of 10 000 ohms may be used. If the line is central energy, condensers should be placed in series with the carbons, but if magneto the condensers should be omitted. It may be found necessary to slightly adjust the resistances to get a perfect balance. These resistances should be placed at each instrument in addition to the regular protectors. The resistance placed at each instrument should be at least 5 000 ohms multiplied by the number of telephones on the line. A telephone line paralleling a power line should, of course, be transposed regularly. Every fifth to eighth pole is good practice. A grounded repeating coil might be used, but it would not remove the difficulty as completely as the above arrangement because it would transmit electrically one-half the difference between the two leakage currents. If, however, the two sides of the line had nearly the same insulation to ground, the repeating coil would be sufficient. See No. 242. E. B. T.

548—Blackening of High-Tension Aluminum Conductor—We have a 33 000 volt, 60 cycle, three-phase transmission line, 30 miles in length. The conductors which are No. 1 stranded aluminum cable spaced four feet apart, were erected about seven months ago. About two-thirds of the line has been in service

for five months and one-third of it for one month. For some reason the conductors on the first section of the line are discolored until they are almost black, while the section which has not been in service so long shows very little discoloration. This change of color obviously is not due to any local condition along the line, as there is a 4 000 volt secondary line on the same poles, erected at the same time and of the same size of aluminum cable, which is as bright as when it was installed. What is the cause of the 33 000 volt conductors becoming black?

J. B. C.

This phenomenon has often been noted, the first time being many years ago, and is not peculiar to aluminum, as might be inferred from the question. An accepted explanation and one which seems not to fail to explain any case heretofore observed is that the blackening noted is due to the bombardment of the high-tension conductor by finely divided solid particles in the air due to the alternating electro-static stress. Low-tension conductors also acquire the same coating eventually, although the time required is greater on account of the difference in the violence of the action. Accompanying the electro-static bombardment there is also probably some oxidation of the surface of the conductor which aids the bombarding particles to adhere to it. Analysis of one sample of the coating so formed showed it to consist largely of carbon with some oxide of aluminum. W. H.

549—500 hp, 500 Volt, 60 Cycle Underground Cable — A three-wire, lead covered cable is to be installed underground for a distance of 635 feet. 500 hp, at 500 volts, 60 cycles is to be transmitted with an allowable drop of 10 percent. I understand that the factors to be taken into consideration are resistance, inductance and frequency. The results which I have obtained by calculation indicate that a 220 000 circ. mil cable would be required; or, allowing for 50 percent over-load, one of 330 000 circ. mils. Will you please give formula for the calculation of such a case and example of its application. There are apparently several ways of arriving at the desired results.

A. T. A.

The power- factor of the load should be known. This is very important, as it affects the current as well as the regulation for a given current. Calculation based on 330 000 C.M., 750 hp, (=560 kw), 80 percent power-factor, 500 volts at receiving end, and a frequency of 60 cycles, gives the following. For purposes of calculation of regulation, and in general, except carrying capacity, it is allowable to calculate as though using two conductors for a single-phase circuit transmitting one-half the power. This gives 448 amperes. The reactance per 1000 feet of conductor is about 0.030 ohms at 60 cycles; the resistance 0.0314 at 68 degrees F. This gives reactance volts for the cable = 17.1, and resistance volts = 17.9, which means a regulation of $17.1 \times 0.6 + 17.9 \times 0.8 = 24.6$ volts. The transmitting voltage would be 524.6 and the percent regulation $24.6 \div 525 = 4.7$ percent—very much better than ten percent. Were the transmitting voltage 500, the current would be larger and the regulation about ten percent greater, e.g., 5.1 percent regulation. At 100 percent power-factor, the regulation would be about 2.8 percent since the current would be less and the reactance would have little effect. A large number of the problems concerning the regulation of a cable must be solved by cut and try methods. One must assume certain conditions and if the results given by these are not as desired, try others. It should be noted that the regulation of say a 1 000 000 C. M., cable transmitting 1 000 kw is not the same as that of a 500 000 C. M. cable transmitting 500 kw, at the same voltage, frequency, etc., except for direct-current or approximately for unity power-factor.

R. W. A.

THE ELECTRIC JOURNAL

Vol. VIII JUNE, 1911 No. 6

Economic Features of Industrial Lighting

With the comparatively recent introduction not only of new but of medium sized light units such as the Nernst, Cooper-Hewitt, Moore, tungsten, tantalum and metallized filament lamps, the art of illumination may be said to have developed into the science of illuminating engineering. This change, with the far-reaching possibilities involved in it, is as yet but imperfectly understood by the public at large and time, therefore, will be required to demonstrate the tremendous advantages to be derived from a scientific analysis, now attainable, of any lighting problem as against the cut and try method of arriving at a solution heretofore in common use.

Illuminating engineering when applied to any special case, seeks to determine the light best adapted for the purpose, having due regard for all the conditions, and embraces such factors as quantity, quality, distribution, continuity of service, surroundings, costs, etc. The large variety of light units and the accessory apparatus now available, render a determination of the proper kind of unit no longer a perplexity but a comparatively simple matter. One of the hardest things the illuminating engineer has to contend with, however, especially in interior lighting, is the difficulty in setting down in figures the total economy—not merely in the production of the light itself but also that made possible by its use—which may be effected by a modern system of lighting, and this is particularly true in plants already equipped with lighting facilities, inadequate though these may be in many cases.

Among the several items contributing to the total gain are the following:

1—Decrease in cost of operation and maintenance of the lighting system, or increase in the quantity and quality of the lighting for the same cost.

2—Greater accuracy in workmanship with consequent lessening of defective work.

3—Increase in production with accompanying decrease in cost.

4—Reduced liability of accidents.

5—Lessening of eye strain.

6—More cheerful surroundings.

It will be seen from this list that while the first of these items will readily be appreciated by everybody, since it can be measured in exact money values, such is not the case with the others; in fact the very existence of some of them may perhaps be a novel thought to many people who have not given the subject of lighting any particular study. Nevertheless, even though it be impossible to set forth in advance the exact savings which will result from these other causes, the arguments for them are so reasonable as to appeal in greater or lesser degree to every one who has occasion to consider the matter.

The present issue of the JOURNAL contains, among other articles on the subject of illumination, two of intensely practical value by Mr. C. E. Clewell on factory and office lighting respectively. In these articles, specific examples of successful lighting have been selected for discussion, the governing conditions being set forth, the various tests that were made fully described, and reasons assigned for the conclusions reached. Rules for sizes of lamps, spacing distances, etc., have also been given, by means of which almost anyone can make the necessary calculations for the more simple installations. It is to be noted, however, that certain constants are involved in these rules that are the results of a vast amount of experimental data accumulated by various investigators; and while perfectly reliable as far as they go, are not intended to cover all cases. Instances may, therefore, occur when it will be necessary to make additional experiments similar to those described in order to meet the actual conditions most acceptably. C. B. AUEL

Modern High Speed Elevators

Modern methods of transportation have made a great change in the geographical distribution of population in large centers. Urban and interurban lines have made it possible for large numbers of people to reside in comfortable and healthful locations and still attend to their work in crowded cities. In a like manner the modern high speed elevator has made possible the concentration of large numbers of people for business purposes in tall office buildings which are well lighted, well ventilated and in which intercommunication is exceedingly easy. The modern sky-scraper would be a practical impossibility without its bank of elevators and, as the

height of these buildings increased, increasing demands have been made upon the elevator builders for machines which would be satisfactorily operative for greater and greater heights. The article by Mr. Hymans on "Direct Traction Electric Elevators", in this issue of the JOURNAL, describes a comparatively recent development in elevator design which is especially applicable to very high buildings. The gearless direct traction type of elevator is the simplest yet developed and follows along the same line as numerous other inventions in which the final and accepted form does away with the initial complications and becomes comparatively simple.

In the direct traction type of elevator, the motor is usually placed at the top of the hatchway directly over the elevator car, and the hoisting cables pass from the car up to the traction sheave on the armature shaft and make a continuous cable connection between the car and counter-weight.This method has proven extremely satisfactory for high speeds. The machine as finally developed is provided with numerous devices which make what is considered the safest and most reliable elevator of the present day.

In a large building such as the Oliver Building the dispatching of elevators becomes quite a problem and, as carried out in this building, the cars can be operated on a regular schedule, the dispatcher being at all times informed of the location of each car. With the various signaling devices used in such an installation travel is much more satisfactory than in ordinary small installations, as the cars are kept running at very frequent intervals and special express service is provided for those occupyng the upper floors. These particular elevators are not only provided with all possible safety features, but the hatchway doors are equipped with contacts so connected with the electric control circuits that a car cannot be started while any door in its hatchway is open. This eliminates the most fruitful source of elevator accidents, that of starting a car while a passenger is attempting to get on or off.

For many years the vertical geared hydraulic elevator was by far the most generally used for office buildings where the rise or travel of the elevators was high, and safety and speed were at all important. More recently the vertical plunger elevator became a strong contender, but after about eight years' trial for high rise work, has proven less satisfactory and its popularity is waning. Both are being supplanted by the gearless traction machine, which is adapted for higher rises and speeds, and which gives smoother

operation, better economy, takes up less space in the building and is as safe an elevator as modern engineering has been able to devise. Despite its smoothness of operation, the acceleration and retardation in starting and stopping are so rapid that for a given car speed it will carry more passengers per day than any other type of elevator.

Each of the high rise elevators in the Oliver Building average about 33 car miles per day, which means that each car makes an average of 231 round trips. As each car will hold about 15 passengers, an average of six or seven passengers on each trip, would aggregate 3 000 passengers per day for each car. The demand made upon elevators in office buildings can readily be appreciated when it is realized that the average business man takes but one trip down town in the morning on a train or trolley car and one back at night. Whereas he takes an elevator to his office, makes one round trip for lunch, several more during the day to keep appointments, and finally comes down in the elevator at night; so that for every round trip on a trolley car the business man will average several round trips on the elevators in his own and other office buildings.

In view of the enormous number of persons using elevators and the rapidity with which they are handled, it speaks well for the safety of this class of apparatus that there are so few accidents; in fact, compared with any other form of transportation, the percentage of accidents on elevators dwindles to insignificance.

F. E. Town

American Association for the Conservation of Vision

It is one of the idiosycrasies of human nature to overlook that which is nearest at hand and reach out for the distant and often unattainable. The native inhabitant of a city is notoriously ignorant of its peculiarities and special attractions; and it is an equally well known fact that improvements and discoveries in the arts have largely been made by those who had not been brought up in the cult. Blindness has always existed and has therefore been assumed to be a necessary evil and, although the medical fraternity has long known that a considerable part of blindness is due to easily preventable causes, it has made no concerted effort to educate the public in regard to the nature of the causes or the means of preventing the dire results.

About a dozen years ago Dr. F. Park Lewis, an ophthalmologist of Buffalo, became impressed with the need of such public

education and began a propaganda of arousing public sentiment, both within and without the professional lines of medicine. As a result of his work a number of committees and local organizations were formed having for their object the prevention of blindness. At first these directed their attention particularly to the subject of "ophthalmia neonatorum," a form of blindness due to contagious infection of infants at birth, and which is responsible for from fifteen to twenty-five percent of all total blindness. As interest in this work grew, other preventable causes of blindness were added to the list, until the subject reached its logical conclusion, that of considering not only the prevention of total blindness but of all injuries and impairments to the vision. Since light is the agency through which vision is accomplished, the subject of illumination of necessity formed a vital part of this broader subject of the conservation of vision.

In order to better carry out the larger work of conserving vision, a national organization was formed having the title of the "American Association for the Conservation of Vision." The general work of the Association naturally divides itself into several rather distinct subjects. In order to carry this out systematically six different departments are provided, viz.,—department of disease and defects of the eye; educational department; industrial department; department of statistics and information; department of legislation, and department of publicity.

Each of these departments is conducted by a director with a staff of five associates, and such sub-committees as may be helpful or needful from time to time. The educational department is now working with a special committee of the National Educational Association on the subject of the care and preservation of the eyes of school children. The lighting of school buildings, both by natural and artificial means, are among the subjects which this department will carefully investigate. The industrial department will have the co-operation of the American Medical Association, headed by Dr. William Campbell Posey, of Philadelphia, which is taking up the subject of the preservation of the eye in industry, including, of course, the subject of illumination. Another committee of the American Medical Association, formed especially to investigate the subject of accidents to the eye, headed by Dr. Mark D. Stephenson, of Akron, Ohio, will also actively co-operate with the industrial department.

The Association will make a special effort to carry out such comprehensive investigations as to develop definite standards of practice, of which there is now a general and sad lack. Perhaps the most important work of all to be accomplished by this Association is the education of the public to the necessities, as well as to the possibilities, of caring for the eyes, from the prevention of total blindness at birth to the proper conditions for their use throughout every stage of life. To this end an active publicity campaign will be carried out through public lectures, the distribution of literature, public exhibitions, etc. Active co-operation will be taken up with the various state and local organizations, and similar organizations created wherever it may seem propitious to do so.

The officers of the Association are: President, Dr. F. Park Lewis; Vice-President, E. L. Elliott; Secretary, Mrs. Ida B. Hiltz; Treasurer, Samuel Ely Eliot, and the Association offices are in the Engineering Societies Building, 29 West 39th Street, New York City.

E. L. ELLIOTT

Twenty-fifth Anniversary of the Transformer

The twenty-fifth anniversary of the commercial introduction of the alternating-current transformer in America, was celebrated by a dinner to Mr. William Stanley, by the Pittsfield Section of the American Institute of Electrical Engineers on Thursday, May 4th. The toastmaster, President Jackson, five Past Presidents, Martin, Thompson, Sprague, Steinmetz and Scott, and the other speakers, E. W. Rice, Jr., Parley A. Russell, Frederick Darlington and Walter S. Moody, had nearly all been associated with Mr. Stanley in one way or another twenty-five or thirty years ago.

Mr. Stanley told a most interesting story of the ideas and efforts which resulted in the first transformer, then called a converter, and the first commercial alternating-current service. It is difficult for those familiar with present theories and methods to really understand how vague were the ideas regarding alternating-current twenty-five years ago. Mr. Stanley said that the principal electrical workers had for several years appreciated the serious limitations of the 110 volt circuits which were employed for incandescent lighting. The three-wire system was a great advance. Various methods of using constant current arc lighting machines were attempted, one of these being the series-parallel method in which different lighting circuits, each supplying lamps in parallel, were connected in series. When fewer lamps were used on one circuit than on others, resistances were sometimes introduced to

compensate for the lamps which were not burning. In other cases, storage battery cells were used. Mr. Stanley, at one time, proposed using alternating current and induction coils having a counter electromotive-force on alternating current corresponding in a way to that of the storage battery on direct current. Other plans were thought of, all aiming at a method of employing a high voltage on the dynamo and in the circuits and at the same time securing approximately 100 volt service for incandescent lamps.

In 1883, Lucien Gaulard brought out in England an alternating-current system in which induction coils were operated in series. The several "inductoriums" or open magnetic circuit transformers were connected with their primary windings in series, while their secondary windings had the same number of turns. This, however, was a constant current and not a constant potential system so that the lamps on the secondary circuits were subjected to serious changes in voltage if the number of lamps on a transformer secondary circuit was varied. This system, however, awakened interest and inspired hope.

In 1885, while Mr. Stanley was engaged principally in the development of the incandescent lamp for Mr. Westinghouse in Pittsburg, the latter purchased the Gaulard and Gibbs patents. A contract arrangement was made by which Mr. Stanley should undertake the development and adaptation of the alternating system for commercial service. In the Fall of that year, Mr. Stanley set to work in an old disused rubber mill at his home in Great Barrington, Mass., and constructed about a dozen transformers, each wound to reduce the 500 volt main line potential to 100 volts in the secondary circuit. These transformers differed from the Gaulard "inductoriums" in having the primary wound for a relatively high potential, and in having the primary terminals connected in parallel to a constant potential circuit instead of being connected in series in a constant current circuit. The coils were made with a closed magnetic circuit and the general proportions of the transformers were remarkably similar to those of the modern "Shell Type." The idea of a counter electromotive-force of approximately 500 volts which, when connected to a 500 volt circuit, would resist the flow of current through a primary coil having a resistance of only one ohm, was so palpable a violation of Ohm's Law that it was almost beyond the comprehension of the electrician who was familiar with direct-current phenomena.

Regardless of popular ideas, the transformers gave good promise and a Siemens machine, which had been imported from England for tests at Pittsburg, was employed as a generator and the transformers were erected in the Spring of 1886 and properly connected for supplying a number of stores in Great Barrington with current on a commercial basis. The plant continued in operation for several months until a screw-driver was accidentally dropped into the dynamo and wrecked the coils.

Mr. Stanley's own story of this interesting history was supplemented at the Anniversary by a letter which I had the privilege to present, giving Mr. Stanley's own account of the starting of this plant, written by himself at the time.

The success of this initial plant led to the commercial adoption of the alternating-current system by the Westinghouse Electric Company. The misgivings of experts, the apprehensions of the dangers of high voltage, the antagonism of opposing commercial interests did not prevail and the little 25-light transformers opened the way for a new era in electric development.

Twenty-five years ago, direct-current incandescent lighting at 110 or 220 volts and direct-current series arc lighting comprised practically the whole of the electrical industry, and the direct-current railway was in its earliest stages. The 220 volt system has still the same limitations as to distance, while much of the current it now uses is first generated and transmitted as alternating current. Direct-current arc dynamos have practically disappeared and the current for arc lighting and much of that used for electric railways is now generated as alternating current, although it may later be converted into direct current. Generally speaking, nearly all electrical energy is now generated as alternating current, and a large portion of this electrical energy is utilized in motors, lamps and other devices as alternating-current.

In a quarter of a century transformers have increased in size 10 000 fold, and practically all electric energy now used passes through at least one transformer and sometimes two or three. The past trend and the future plans for electrical development depend upon the transformer.

Well may we do honor to Mr. Stanley, the electrician and inventor, and to Mr. Westinghouse, the engineer and manager, for their foresight and courage in undertaking and promoting a development which means so much to the electrical industry and to the public welfare.

CHAS. F. SCOTT

MR. STANLEY'S REPORT OF THE STARTING OF THE FIRST ALTERNATING-CURRENT PLANT IN AMERICA

Laboratory of William Stanley, Jr.,
Great Barrington, Mass., 3-17-86.

George Westinghouse, Jr., Esq.,
Pittsburg, Pa.

My Dear Sir:

* * * * * *

I am pleased to be able to inform you that the secondary system is being rapidly completed. As I mentioned some time ago, I believe the true way to study it is to give it a commercial test here in town. I have, therefore, run wires from the laboratory to the village and have placed a converter in my cousin's store in order to test the commercial necessities.* The lamps in the store were running last night. I expect to have three or four lamps in the hotel (The Berkshire House) and in three or four other stores running in a few days more. In short, I expect to have a demonstration of the system ready for inspection within two weeks time, perhaps sooner. The Siemens machines, while they work well, have no self-regulation, and I am therefore anxious to have the new alternate current dynamo now at the shop tested to determine this point in it. As I thought it better, I have borne the expense of the little town plant myself. All the converters are under lock and key, so that no one knows anything about them. I have had dies made to stamp the new converters, and believe that this size, viz., 25-16 c. p. lights, is satisfactory. May I, as soon as I am ready, write Mr. H. H. Westinghouse and Mr. Kerr to come up and see the plant? I did not intend to have it known at all, but Mr. Davis, of W. C. K. & Co. came up to fix the engine plant and saw the lamps, etc. I asked him to say nothing about it in his travels. My head troubled me some time ago so much that I ran away a week to Savannah and back by steamer, and am now much better, I am striving all I can to finish this system for you at the earliest possible date, but it is expensive work. Possibly you will allow me a longer rest when I have finished my work. I might say a great deal about the system, but briefly, it is all right. I am, sir,

Yours truly,

William Stanley, Jr.

I will send a fuller report in a few days. I am now right in the midst of the work. The working drawings for the converters will be ready very soon.

FACTORY LIGHTING PROBLEMS

C. E. CLEWELL

HOW much is the accuracy and general quality of workmanship improved by good instead of poor light?

How much does the stimulating effect of bright surroundings contribute to cheerfulness of mind and alertness of action?

How many mistakes in reading figures on blueprints or on scales are due to poor light?

How much fatigue and eye strain and impaired vision is caused by inferior or improper lighting?

How much are accidents to machinery and to workmen decreased by having good instead of poor light?

It is difficult to answer these questions in a definite manner, but no one familiar with industrial conditions will take exception to the statement that good light is better than bad light. And if it can be shown that the actual cost of good light is small compared with the value of the advantages secured, then poor lighting has no defence.

The practical problems involved in planning a lighting system are the determination of the factors which constitute good lighting, by careful study of the exact conditions under which the light is to be used, and the adaptation of the means at hand to these conditions. Simple as these problems may seem, when carefully analyzed, they will be found to be much more intricate and involved than might be expected.

RELATION OF THESE PROBLEMS TO EFFICIENT MANAGEMENT

In factory work efficiency should be considered from at least two viewpoints; in the one case, that of the machine, and in the other, that of the workman. The surrounding conditions under which work is done are of prime importance when considering the items which contribute to man-efficiency. Among these conditions is that of artificial light. Poor light produces a bodily and mental discomfort which seriously affect the man and his work. When the work is seen with difficulty, when the drawings are indistinct and the surroundings dim and gloomy, the conditions necessary for high efficiency are lacking. In those instances, therefore, where superior light improves the physical characteristics which tend toward a better class of work and affords more cheerful conditions, it should, without question, be provided.*

*See "Notes on Factory Lighting," by the author in the JOURNAL for March, 1910.

CLASSIFICATION OF PROBLEMS IN FACTORY WORK

A classification, in complete form, of the various cases included under this head will be hardly possible of successful accomplishment. Factory lighting might be grouped according to surroundings, that is, whether ceiling and walls are light or dark; the presence or absence of line shafting and belting; the work, whether flat, as in the case of some bench work, or consisting of high machines and other obstructions to the light. It might also be grouped according to the height of ceiling and width of location, although in such a scheme two spaces of the same dimensions and ceiling height, might call for entirely separate illumination plans due to other conditions as before suggested. For these reasons a complete classification of work of this kind is hardly possible or even advantageous. It has, however, been found convenient and helpful in a given factory to separate the lighting problems in the various locations according to ceiling heights because the size of lamps and their spacing depend to a large extent on this factor. Low ceilings generally call for small or medium sized lamps, while large lamps are more applicable to the higher ceilings and mounting heights.

Certain illumination data, which has been taken from actual installations in a factory, is shown in Table I. The information contained in this table is not intended to serve as a rule for factory work in general, but may be used as a guide in other locations where the ceiling height corresponds and where the surroundings are comparable. It will be noted that the data in this table refers to tungsten lamps. The tungsten lamp is a type of the medium sized light unit which has done much to promote rapid strides in illumination as applied to factories. While special references are made to tungsten lamps in this article, the principles and general notes apply with equal force to other lamps of medium size such as the Cooper-Hewitt and the Nernst lamp.

Certain Items Bearing on Effective Illumination The intensity of illumination* on the working surface is one of the important items which determine the success or failure of any lighting system. The eye is affected by the intensity of the light reflected from the

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*The terms "Illumination" and "Light" are used by some to indicate the effect on the work and the effect from the lamp respectively. This terminology is not yet popularly recognized and the terms are often used interchangeably.

object, rather than by the intensity of the light thrown on the work. Hence where the objects are of a very dark nature more downward illumination may be required for a certain factory space

TABLE I—EXAMPLES OF FACTORY TUNGSTEN LIGHTING SYSTEMS*

Ceiling or Girder Height Feet and Inches.	Mounting Height Above Floor, Feet and Inches.	Spacing Distance, Feet and Inches.	Size of Lamp, Watts.	Watts per Sq. Ft.	Class of Work and Character of Surroundings.†
8-1	7-6	8-0× 8-0	60	0.96	Detail Work—Light Ceiling, No Walls
9-0	8-6	8-0× 8-6	100	1.60	Bench Work, Flat—No Ceiling, Dark Walls
11-1	10-3	8-0× 8-9	100	1.56	Bench Work—No Ceiling, Dark Walls
11-9	11-0	8-0× 9-6	100	1.56	Machining—Dark Ceiling, No Walls
11-9	11-0	8-0× 8-9	100	1.56	Machine Work—Dark Ceiling and Walls
12-0	11-3	8-0× 8-0	100	1.54	Machine Work—Dark Ceiling No Walls
12-0	11-3	7-0× 8-0	100	1.67	Machine Work—Dark Ceiling No Walls
12-0	11-3	7-0× 8-0	100	1.79	Bench Work—Dark Ceiling, No Walls
12-6	12-0	8-0×10-0	100	1.25	Machine Work—Dark Ceiling No Walls
13-8	12-10	8-0× 8-6	100	1.54	Machine Work—Dark Ceiling and Walls
16-0	14-6	8-0× 8-9	100	1.61	Detail Work—No Ceiling, Dark Walls
16-0	15-2	8-0×10-0	100	1.30	Rough Work—No Ceiling, Light Walls
16-0	15-2	11-0×16-0	250	1.23	Painting Machines—No Ceiling, Light Walls
16-0	15-2	10-0×12-0	250	1.76	Fine Die Work—No Ceiling, Dark Walls
16-0	15-2	13-0×14-0	250	1.18	Bench Work—No Ceiling, Dark Walls
24-9	21-3	10-0×12-0	250	1.85	Fine Assemb. Work—Dark Ceiling, No Wall
24-9	21-3	10-0×12-0	250	2.00	Machine Work—Dark Ceiling, No Walls
24-9	21-3	10-0×12-0	250	1.66	Testing—Dark Ceiling, No Walls
25-2	21-7	10-0×12-0	250	2.35	Testing—Dark Ceiling, No Walls

than where the work is light in color. For this reason factory conditions often present difficulties in the matter of lighting which are not in evidence in office work. The required intensity of the light for various kinds of work is an item impossible completely to

*The installations here referred to are not in general provided with drop lamps, the over-head light being sufficient for nearly every case.

†In factory construction, manufacturing spaces often occur where the girders and columns form the boundary lines without walls. Similarly open girder construction often occurs, where no ceiling exists between the floor and the roof.

specify. It has been found that 2.5 foot-candles* on the working surface are sufficient in machine work where practically no daylight is present. In other cases where light is required on the sides of the work, and where the work itself is of a nature requiring the distinction of much detail, downward intensities of five foot-candles and over are sometimes necessary.

The intensity of the light is not, however, always the most important feature. In some cases where color contrast is largely lacking, an increase in the intensity will not better conditions, as in matching or assorting based on color differences. In other cases work is based almost entirely on shadow effect. In finishing a die for a punching, dependence may be placed almost entirely on the shadows along the edges of the die in judging of the exactness of the fit. In an instance of this kind, a drop lamp in the hands of the workman will be far better than any amount of overhead illumination, no matter what the intensity.

REFLECTORS FOR UNIFORM ILLUMINATION

Uniformity of the light on the working surface may refer either to the vertically downward light* or to some other component. The vertically downward light is, however, most often referred to when the term "uniform illumination" is used. Uniformity of downward light over the entire surface of a room is generally looked upon as an advantage in a lighting system, and is sometimes the only factor considered.

Reflectors or shades have been made for two purposes. One object is to shield the direct rays of the lamp from the eyes, the other being to re-direct the light from the lamp so as to throw it in the most useful and effective direction. In so far as this scientific side of reflectors is concerned, they are now designed so as to furnish fairly definite results. Rules for the use of such reflectors call for a certain relation between the spacing of lamps and their mounting height if uniform downward light over the entire work-

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*A foot candle is the unit of illumination intensity, and may be defined as the light thrown normally on a surface by one standard candle when the light source and the surface are one foot apart.

*An effort has been made to classify downward light by the term "horizontal" and side light by the term "vertical" illumination. This is based on the fact that downward light is effective on a horizontal plane and in a like manner side light is effective on a vertical plane. If the terms were intended primarily to refer to planes this nomenclature would be appropriate. In as much as the terms actually refer to illumination, the terms "downward" and "side" light are here used for clearness.

ing surface is desired. For example, one type of reflector calls for a spacing of lamps equal to 0.7 of the mounting height above the floor. If this relation between spacing and mounting is followed, uniformity of the downward light may be expected, although other effects such as ceiling reflection may tend to vary the resulting light. In case this relation is violated by mounting the lamps either higher or lower than called for by rules which consider uniformity of the downward light, the resulting illumination on the working surface may depart very radically from a condition of uniformity. The effect on the downward illumination caused by variations in the mounting heights is indicated by Fig. 1. The lower curve, marked with a mounting height of 12 feet 6 inches, shows practical uniformity of the downward light. The remaining curves show the effect on the downward light as the lamps and reflectors are lowered. If, then, uniformity of the downward light is desired, such rules as are indicated by the various reflector companies for the spacing and mounting of lamps for a given reflector, should be adhered to.

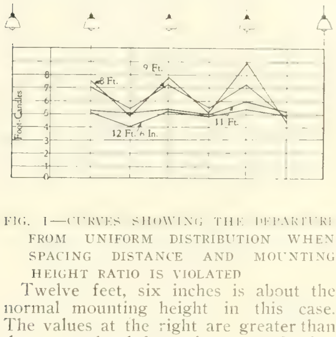

FIG. 1—CURVES SHOWING THE DEPARTURE FROM UNIFORM DISTRIBUTION WHEN SPACING DISTANCE AND MOUNTING HEIGHT RATIO IS VIOLATED

Twelve feet, six inches is about the normal mounting height in this case. The values at the right are greater than those on the left, owing to reflection from a white column.

With a light ceiling, the reflection of that part of the light which passes through the reflector to the ceiling, and which is added to the light thrown downward from the reflectors, is a factor in building up the intensity of the illumination on the working surface. In a case of this kind uniform illumination is obtained by the use of almost any reflector whether designed for the purpose or not, provided the lamps are fairly close together. In fact, tests indicate that if lamps without any reflectors whatever are installed in a room with a light ceiling, fairly uniform illumination will result. In this case, however, the bad effect of an unshielded lamp will call for a reflector of some kind. It should also be stated that while uniform light may result where no reflectors are used, the intensity of this light when measured on the working plane may be increased by as much as 60 percent by the use of efficient reflectors. This is due to the utilization of the horizontal rays of light, which

predominate in the bare tungsten lamp, whereas the most effective light in factory work will usually be that which is directed downward.

Side Lighting—In factory work it will sometimes be found that the downward light, which is usually given the greatest weight, is not of greatest importance. It is frequently far more desirable to light the side of a machine or of a piece of work than any other part. If, in making an installation of tungsten lamps, the layout is made to produce the most efficient downward illumination, it may happen that the side component of the light is so small that the sides of machines are inadequately lighted.

Experience indicates that there are two ways in which to secure greater side light. One of these is to lower the lamps, the other to use broader distributing reflectors than called for by rules which consider only the downward illumination. If it has been determined that a certain reflector in an installation with given spacing and mounting of the lamps will produce uniform downward illumination on the working surface, and if it is later found that more side light is necessary, more broadly distributing reflectors may be decided upon, but their use is apt to result in an insufficiency of downward light, that is, the increasing of the side light will decrease the downward light. To bring up the downward intensity to the proper value, larger lamps may be substituted, and sufficient side light as well as adequate downward light will result. A series of curves, which show how the side light is affected for a given mounting height by the use of concentrating, distributing, and very broadly distributing reflectors, respectively, is given in Fig. 2. The ordinates in these curves indicate the measured intensities of the side light on a horizontal plane about three feet above the floor. It will be noted that the side light is highest in each case with the broadly distributing reflectors, but companion observations indicate that while the side light is greater, the downward light is reduced. The three lower sets of curves of Fig. 2 indicate the variations in side light intensity with different mounting heights of the lamps and various types of reflectors. It will be noted that the side light increases as the lamps are lowered. Fig. 2 also indicates the variations of the side light with different mounting heights and the same reflector.

Glare—One of the most pernicious effects of the tungsten lamp is the glare produced by its intensely bright filament when unshielded from the eye. It has been stated that eye strain and eye

trouble were greatly increased when the carbon filament lamp was introduced. This being true, a far greater tendency in that direction

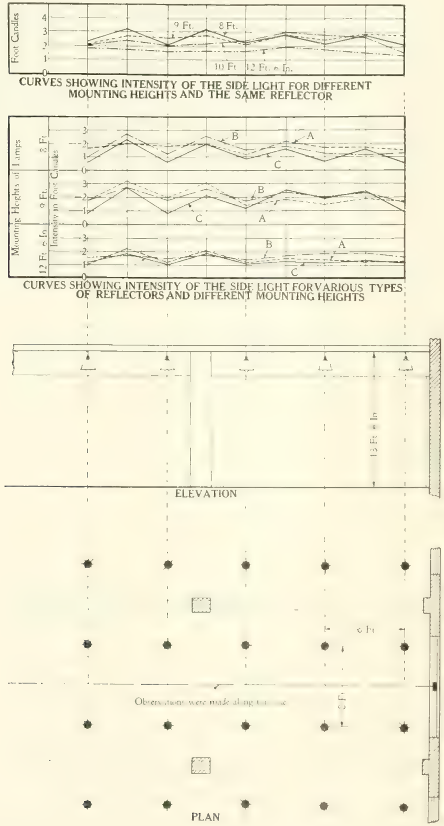

FIG. 2—DIAGRAM OF LAMP ARRANGEMENT AND CURVES SHOWING EFFECT OF MOUNTING HEIGHT OF LAMP AND VARIOUS TYPES OF REFLECTORS ON THE SIDE LIGHT

In these curves the intensity of the side light is indicated by the ordinates. One observation station was directly under a row of lamps in each case, the other station being midway between rows.

A—Broadly distributing. *B*—Distributing. *C*—Concentrating.

is likely to be felt as the tungsten lamp becomes more generally used, unless proper precautions are taken to shield the lamps by

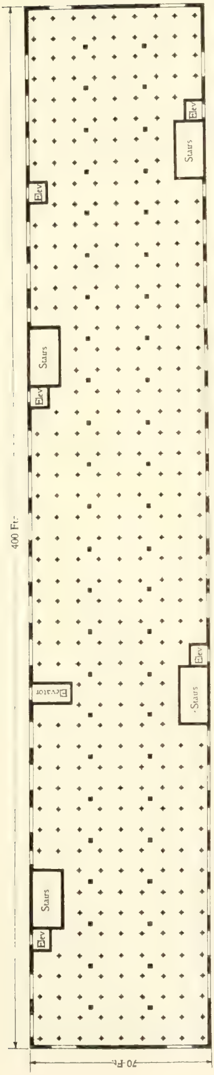

FIG. 3—PLAN OF ONE OF THE FLOORS IN EIGHT-STORY BUILDING
Showing arrangement of lamps in manufacturing space.

suitable shades or reflectors. In factory work the points which have a large bearing on the glare are: 1—Mounting height of lamp; 2—Size of lamps; 3—Spacing of lamps, and 4—Type of reflectors used.

As a general rule it is best to mount all lamps well out of the range of vision. The argument that the lamps should be close to the work for the purpose of gaining the greatest effectiveness from the lamps is poorly founded, since the increase in light by mounting them low may be more than offset by the evil effect on the eye produced by lamps mounted in the line of vision.

The size of the lamps has much to do with glare. It has been found that where the ceiling is low a small lamp is not nearly so trying to the eye as a large lamp.

The spacing has a certain bearing on the glare, since the closer the lamps the smaller may be their size to provide a given intensity.

While modern reflectors have as one of their greatest claims the resulting increase in efficiency, the protection afforded in shielding the bright tungsten filament is also a very important item.

Very often in factory construction, glare may be much reduced by mounting the lamps so that they are protected by some feature of the building construction. Thus in the room shown in Fig. 6, the girders afford an excellent protection for

the eye, while in that shown in Fig. 10 the lamps are all visible down the aisle when a workman looks up from his work.

A TYPICAL FACTORY LIGHTING PROBLEM

As a typical example of factory lighting in which many applications of the principles previously stated are in evidence, a factory building will be considered which contains more than 225 000 square feet of floor space and in which over three thousand tungsten lamps have recently been installed. This building, a plan of which is shown in Fig. 3, consists of eight floors, mostly devoted to the manufacture of detail apparatus. The walls are light in color and the building has the advantage of a light ceiling. The height from floor to ceiling is 13 feet 6 inches and the building is divided into

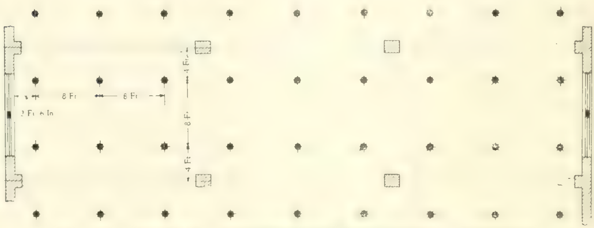

FIG. 4—TYPICAL BAY SHOWING ARRANGEMENT OF LAMPS IN A MANUFACTURING SPACE

bays of 16 by 70 feet. The work may be classified into bench work, requiring in many cases excellent side light; machining work, where line shafting and belting form an obstruction to the light; assembly work, often performed on the floor where side light is imperative; and a storage warehouse, where a low intensity is sufficient. One floor is specially reinforced by girders covered with cement, which project below the ceiling of the floor below, thus forming an obstruction to the wiring. In this case the moulding was cut and run so as to follow these girders.

The ceilings are of wood and hence wooden moulding was advantageously used. Switches were placed on central columns, on the same side of the aisle throughout and on the same relative side of each column wherever possible. In feeding the switches, iron conduit was run down the cement columns and iron outlet boxes served the double purpose of supports for the snap switches and of

wall receptacles as outlets for extension lines when required.

Lighting Requirements—The requirements for the lighting in this building may be enumerated as follows: 1—Sufficient general light for all ordinary purposes. 2—Higher intensities in some places than others. 3—Strong downward light in certain locations. 4—Strong side light in certain locations. 5—Glare reduced to minimum.

One of the very trying conditions was that of providing sufficient light for the classes of work where varying intensities were necessary, and at the same time of making the system universal enough so that work could be done with equal ease at any portion of the floor space. This feature was taken care of by providing outlets with standard spacings all over the building except in the ware-

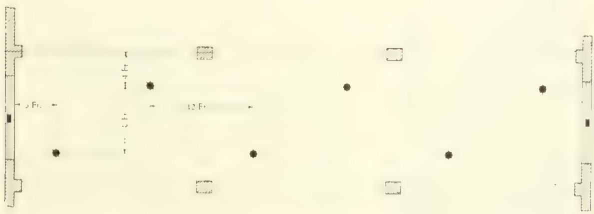

FIG. 5—TYPICAL BAY SHOWING ARRANGEMENT OF LAMPS IN WAREHOUSE

house and storerooms, and by varying the intensity where necessary by a change in the size of lamps. It will be seen that this is an excellent feature of a distributed system of lighting, since a change in the size of the lamps and reflectors in no way changes the uniformity or the acceptability of the resulting illumination.

Experiments and Steps Leading to Final Arrangement—As a first step several bays on one of the floors were equipped with 100-watt tungsten lamps spaced 8 feet apart and 2 feet 6 inches from walls, the lamps being mounted at the ceiling. This size of lamp seemed best adapted to the ceiling height, and the size of bay was not only very suitable for this spacing (since 18 lamps filled one bay) but the arrangement was symmetrical with respect to the bay as well. The ratio of spacing distance to mounting height called for concentrating reflectors, which were installed along with bowl-frosted lamps. Several adjoining bays were equipped with lamps

of the same size but with varying types of reflectors, both glass and metal. These trial bays were left in service for several months so that the opinions of all concerned, including the workmen, could be obtained, and also for the purpose of making tests and noting the effect of dust and dirt on each type of reflector. Six lamps were controlled per switch, thus requiring three switches per bay, all three switches being mounted on one column. A trial was also made of several bays with bare lamps to note whether the resulting illumination was noticeably less than that with reflectors. It was thought that the shielding effect of the girders might serve as a

FIG. 6—MANUFACTURING SPACE WHERE SIDE LIGHT IS IMPERATIVE

Note the comparative absence of glare due to the shielding effect of girders. This view was taken at night on the fifth floor.

sufficient protection for the eyes of the workmen without the addition of shades or reflectors. Furthermore, various mounting heights and various shapes of reflectors were tried for the purpose of investigating the proportionate relation of downward and side light. The same procedure was also tried with other sizes of lamps and reflectors so as to determine whether the size nominally selected was suitable for the purposes.

Notes on the Final Arrangement—The main results from these experiments covering several months, are as follows:—

1—The 100-watt lamps seemed the best average size, but at least two intensities were found advisable, one somewhat high for detail and machine work, and a lower intensity for general assembly work.

2—Of the various mounting heights tried, it was found very desirable to mount the lamps as close to the ceiling as possible, so that glare was reduced to a minimum.

3—The general scheme of installing 18 lamps per day seemed best.

4—The switching of six lamps per circuit, while possessing some good features, did not seem a sufficient sub-division. At times the work directly next to windows was sufficiently lighted by daylight, while the work under the second row of lamps was insufficiently lighted. This led to the conclusion that the lamps next to the windows in each bay should be on one switch, and four lamps per switch in general seemed a better arrangement than six.

FIG. 7—MANUFACTURING SPACE WHERE VERTICALLY DOWNWARD LIGHT IS IMPORTANT

This view was taken at night on the fifth floor.

5—It was found after several months of service, during which time the reflectors were allowed to remain uncleaned, that tests on each of the reflectors before and after cleaning indicated about the same degree of reduction in efficiency. It was noted, however, that reflectors located near belting became covered with dirt in very much less time than when the lamps were in a clear open space.

6—While the ratio of spacing distance to mounting height of the lamps called for a concentrating reflector for producing uniform downward light, a distributing reflector was essential for the purpose of providing the necessary side light. An intensity of about two foot-candles on the sides of machines seemed to be sufficient.

For the reasons previously stated, the sacrifice in downward light so as to realize the required side light, was made up by the use of higher candle-power lamps in certain portions of the building than originally contemplated.

7—Bowl-frosted lamps proved not so desirable as clear lamps, due to the more rapid effect of dust and dirt on the frosting than on clear glass. This effect is, of course, particularly noticeable in factory work.

8—Metal reflectors were far inferior to glass because of the fact that no light passes through them. Glass reflectors, on the

FIG. 8—MANUFACTURING SPACE WHERE BENCH WORK CALLS FOR BOTH DOWNWARD AND SIDE LIGHT

This view was taken at night on the sixth floor.

other hand, permit some of the light to pass through the reflectors and to be in turn reflected from the light ceiling and walls.

9—Lamps without reflectors were debarred on account of the glare which resulted when a man looked up from his work, and further, since 62 percent more light on the working surface was produced by lamps equipped with reflectors than with lamps of the same size alone, it was considered a doubly good investment to provide all lamps with reflectors.

Some Comments on This System—This tungsten lighting system has now been in service long enough to indicate that for a

majority of the work in this building the illumination facilities are unusually satisfactory. Experts have viewed this lighting arrangement and have expressed the opinion that this particular factory is one of the best lighted buildings in the country, representing many valuable points of recent illuminating practice. While a great many individual lamps were used previous to the new lighting system, and while it was thought by workers and foremen that they would have to be left in service notwithstanding the new over-head lighting installation, nevertheless practically all individual lamps were taken out with the understanding that they would be put back after several weeks if found necessary. Although the object has been to

FIG. 9—MANUFACTURING SPACE WHERE IT WAS DESIRABLE TO HAVE LIGHT ON THE SIDES OF MACHINES

In the foreground the lamps are lowered to clear belting and shafting. This view was taken at night on the seventh floor.

give a sufficiency of light to every workman, it was found that a very much less number of individual lamps were called for than were thought to be necessary at first. Here and there a drop lamp has been installed to take care of special work requiring light at an unusual angle or of more than ordinary intensity; but as an evidence of the acceptability of the light, it may be stated that during the past winter since the new system has been installed, the complaints and calls for changes in the wiring have been negligible when compared to the extreme number of similar complaints during the preceding winter when a system of inferior lighting was in service.

This fact in itself is an unquestionable recommendation of the new lighting system.

One point of interest in connection with this lighting installation is that the final arrangement was the outcome of experience rather than predetermination. Months of careful investigation and trial were made of the various schemes as indicated in the preceding notes and the completed work was decided upon on a basis not only of these tests, but also on the opinions of those who were to work under the lighting. Theory and formula give a general basis, but often fail to take account of certain practical conditions. For ex-

FIG. 10—MANUFACTURING SPACE WHERE BOTH SIDE AND DOWNWARD LIGHT ARE NECESSARY

Note the effect of having lamps below the girders. These lamps were installed so as to hang at the same level as lamps in the side bays and, due to ceiling construction, were unprotected by the girders. Compare with Fig. 6. This view was taken at night on the eighth floor.

ample, the reflection from ceilings and walls; the need for side-light as distinguished from vertically downward light; the color of the machinery or materials; the need for numerous lamps to prevent shadows, and the allowance to be made for dust and dirt on lamps and reflectors, are points which show why many things must be considered, aside from the mere area to be lighted, if satisfactory results are to be assured.

DIRECT TRACTION ELECTRIC ELEVATORS
IN THE OLIVER BUILDING, PITTSBURG

F. HYMANS

SINCE the completion of the new Oliver Building there are three elevator installations of the so-called direct traction type in the city of Pittsburg, the two others being in the Keenan and Highland Buildings. These installations are similar in design, lifting capacity and speed to those installed in the Singer and Metropolitan towers in New York City. The Oliver Building, shown in Fig. 1, occupies the entire frontage on Smithfield Street from Sixth Avenue to Oliver Avenue, with a depth of 120 feet on Oliver Avenue and 110 feet on Sixth Avenue. It is twenty-five stories high above the street level in addition to the basement and a sub-basement, and is the largest and highest office building between New York City and Chicago. The building contains 1 160 offices above the ground floor, which is devoted to banks, railroad offices, etc. A typical floor plan of one of the office floors is given in Fig. 2.

The elevator installation consists of fifteen elevators in two banks of seven passenger elevators each, and one freight elevator, all being of the traction type. One group of passenger elevators is designed for travel from the first to the sixteenth floor, a distance of 210 feet, and the other group from the first to the twenty-fifth floor, a distance of 325 feet, making no stops for the first fourteen floors. They have a maximum lifting capacity of 2 500 pounds and a speed of 550 to 600 feet per minute. Approximately 30 000 people are carried per day, while on rush occasions over 900 people can be carried each way in ten minutes. The express elevators average 270 round trips per day and the locals 220 round trips per day. Naturally the dispatching of the elevators is an item of considerable importance. From the dispatcher's board, shown in Fig. 3, the dispatcher has full supervision over all the cars by means of push buttons and buzzer signals. The operators also receive lamp signals operated by the push buttons on the various floors, and lamps in the halls on the various floors indicate to the waiting passenger which elevator will be the first to stop at that floor.

In addition to the usual mechanical position indicators over the car doors, there is an electric position indicator mounted in the

wall opposite the dispatcher's station, from which the dispatcher can see at a glance the exact location of each elevator. This indicator is of the same type as the one installed in the Singer Building, in New York City. It consists of a number of vertical rows of miniature lamps, one row for each elevator. The number of lamps in each of these rows is the same as the number of floors its respective elevator serves, and the corresponding lamps light as the elevator passes the various floors. For instance, as an elevator in its upward movement arrives at the second floor, the second lamp in the corresponding row of indications is lighted. As it reaches the third floor, the third lamp lights and the second lamp is extinguished. The mechanism for operating the indicator consists of flat contactors for each elevator, each contactor being divided into segments corresponding to the floors in the building and having brushes traveling over the segments, the brush moving in direct relation to the movement of the elevator in the hatchway. That is to say, when elevator No. 1 is at the fourth floor the brushes on contactor No. 1 make contact with the fourth segments.

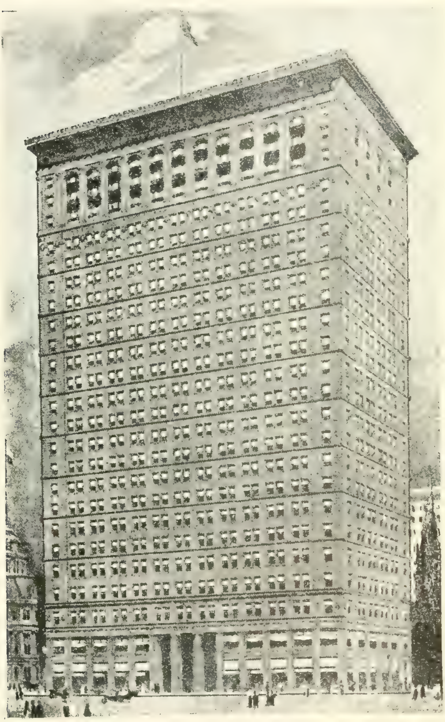

FIG. 1—EXTERIOR OF OLIVER BUILDING, PITTSBURG

In addition to the buzzer system by which all ordinary signals are transmitted to the operators, a telephone is installed in each car just above the master switch as shown in Fig. 4, communicating with the dispatcher's station and with the machine rooms, where an electrician is in attendance. Any unusual orders may thus be promptly transmitted to the operators, and any interruption to the service can be speedily adjusted.

Realizing the importance of safety and efficiency in elevator service, no expense has been saved by the management of the Oliver Building to secure this end. Each of the hatchway doors is provided with contacts, which make it necessary to have the doors

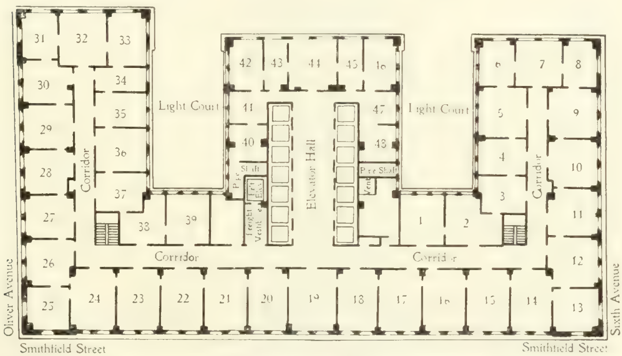

FIG. 2—TYPICAL FLOOR PLAN, OLIVER BUILDING

closed before the elevator can be started, or in case a door should open accidentally the main switch will open and stop the elevator. Emergency gates are concealed in each side of the cars, which provide ample space for transferring passengers to cars in the adjoining hatchways if necessary. Devices are provided which absolutely prevent overtravel of the car at either end of its trip, regardless of the position of the master-switch. Excessive speed of the driving mechanism is prevented by a governor which limits the motor speed and, in case the motor cannot check the over speed, as, for instance, if the cables break, the same governor will operate the car safety device which grips the guide rails, and thus holds the car securely.

THE ELEVATOR MECHANISM

Prior to 1904 elevators installed in high buildings were of the hydraulic type, or if electric, of the drum type with a relatively high speed motor in combination with a worm-wheel driving mechanism. Their limitations as to speed and height of travel were plainly evident and it was on this account that the Otis Elevator Company began the experiments and studies that led to the adoption of the direct traction electric elevator.

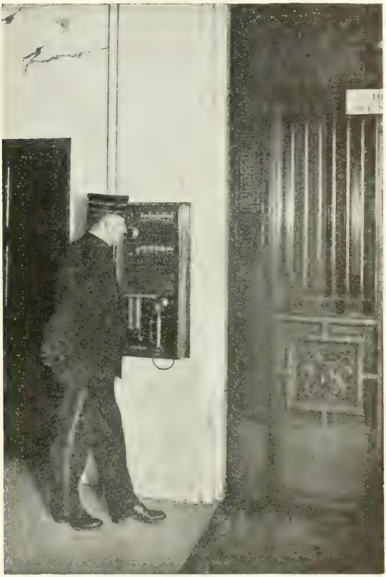

FIG. 3—DESPATCHER'S POSITION, SHOWING SWITCHBOARD*

The problem that presented itself was as follows:—

1—The new machine must be safe.

2—It should be capable of high speeds and extreme heights of travel.

3—It should have, if possible, a high efficiency.

4—It must be noiseless and devoid of vibrations in its operation.

5—It should equal the hydraulic elevator as to speed control.

6—It must permit the making of smooth and easy stops with a stopping distance short enough to permit the operator to gauge his landing accurately.

The mechanical requirements *1* to *4* were found to be embodied in the traction drive principle as shown in Fig. 5. In the direct traction drive the cable from the car passes up to the driving sheave directly over the hatchway, thence around an idle sheave and again over the driving sheave to the counterweight, thereby securing approximately two half wraps over the driving sheave, which is all

*Figs. 1, 3 and 4 are reproduced through courtesy of the *Telephone News*.

the adhesion necessary for ordinary elevator service. For extra heavy duties the number of wraps may be increased. The motion of the elevator car is thus dependent on the adhesion of the cables to the driving sheave due to the combined weights of the car, live load and counterweight, and it is evident that the friction is largely relieved when the car or counterweight lands solidly, whence motion of the car and counterweight stops even though the driving sheave may keep on revolving. This arrangement provides a simple means of preventing over-travel even in case of total failure of the automatic stopping devices at the terminals of the car travel, and constitutes a valuable safety feature possessed only by some types of hydraulic elevators. The means employed for absolutely stopping the cars or counterweights consist of buffers placed in the path of the car and counterweight travel. If the car travels past the top landing the buffer attached to the counterweight strikes the bottom of the hatchway and releases the cable tension. If the car travels past the bottom landing it engages an oil buffer which, as shown in Fig. 6, is made up in addition to a spring at the top, of a piston acting in a cylinder. When the weight of the car comes on this piston it is forced down and in so doing forces oil from the cylinder through openings arranged in such a manner as

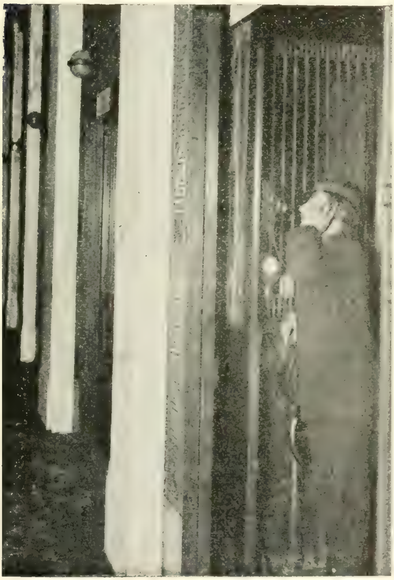

FIG. 4—OPERATOR'S POSITION, SHOWING USE OF TELEPHONE IN CAR

to give a gradual retardation without shock within the distance of the buffer stroke of 35 inches.

It is evident from Fig. 5 that the speed of the car is identical with the circumferential speed of the driving sheave. A car speed of 600 feet per minute would therefore require only 64 r.p.m. of the driving shaft, with a 36 inch sheave. The consideration of the requirements *2*, *3* and *6* lead to the exclusion of gears between driving shaft and motor notwithstanding the necessity of constructing a motor having such an extremely slow speed and the difficulties of its control. The type of machine used in the Oliver Building is shown in Fig. 7. It will be seen that it consists of a bed plate supporting the motor frame and bearings, an armature with extended shaft carrying the driving sheave and brake pulley and of supports for the brake magnet. Mechanically it is of the simplest and most efficient construction, offering no unusual problems, except those of an electrical nature. The motor is a straight six-pole, shunt-wound machine, with cast steel frame. Although it is rated at 35 horse-power it is of large proportions owing to the slow speed, the fields and frame, for instance, weighing about 13 000 pounds and the armature with extended shaft, driving sheave and brake pulley weighing 8 000 pounds. The commutator is 18 inches in diameter, with 4.5 inch face, and has 254 bars. The large number of turns and the length of the circuits in a motor of this type is, of course, responsible for a relatively large armature resistance which is the cause of some variation in speed depending on the load in the car.

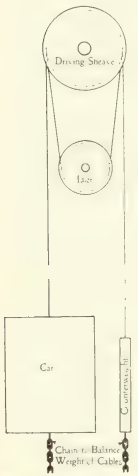

FIG. 5—DIRECT TRACTION DRIVE

The speed of the elevators when lifting the maximum load is 550 feet per minute and when the live load is such that the weight of the car plus the load balances the counterweight, the speed is approximately 600 feet per minute. A governing device is provided limiting the highest attainable speed when there is a load driving the motor to about 700 feet per minute. A general view of one of the motor and control rooms is shown in Fig. 8. A detail view, showing motor, brake, switch board, etc., is given in Fig. 9.

The difficulty in high speed elevator service is not to attain the high speed but to arrange the control so that the stopping distances for all loads are as nearly constant as possible and such that the operator may gauge his landings accurately. This requirement also demands a wide range of speed control. Overrunning of the landing causes not only a loss of time but also a loss of energy, as in returning the elevator to the landing the motor takes full starting current and unnecessary work is done at high expense. On this account the speed control is arranged in several steps, the ratio between the highest and lowest speed being about 10:1. With the motor having already a very low maximum speed it would be commercially impossible to obtain this range of speed by field control only and, sacrificing efficiency to necessity, the motor is provided with one speed reduction through field control in the ratio to the maximum speed of about 2:1, all of the other speeds being attained by the use of resistances both in series and in parallel with the armature. The slow speed armature is particularly suited to speed control as its relatively low inertia causes it to respond to the controller quickly and without perceptible jar. The resistance in parallel with the armature has the additional advantage of giving a dynamic brake action in stopping. The magnetic proportions of the motor fields are such that their self-induction is the cause of a time lag between the making of the field circuit and the establishment of its full sterngth. As this would seriously interfere with the prompt starting of the machine the fields are permanently in circuit but with a resistance in series while the machine is at rest or at full speed, which reduces the current to three amperes at 220 volts.

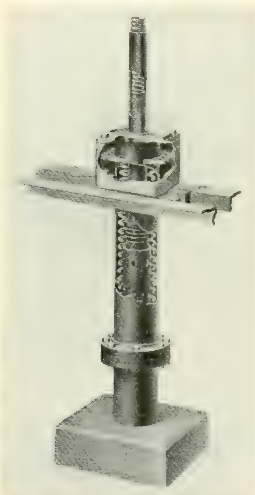

FIG. 6—DETAIL VIEW OF OIL BUFFER

An important part of elevator machines of this type is the brake as the very small mechanical friction of the machinery makes

it necessary to rely on the brake entirely to hold the car at the landing. The brake is essentially a holding brake, that is the shoes are not applied until the machine has practically been brought to rest by dynamic braking and presents as such an interesting development. It would be undesirable to stop high speed elevator machinery of this kind by mechanical braking, on account of the large variation of the stopping distances that would result if a fixed brake pressure were applied to stop elevators having constantly changing loads. Also the wear on such a brake would necessitate continued

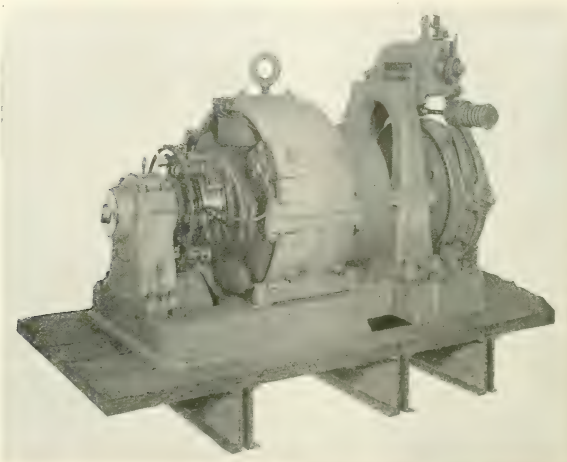

FIG. 7—SLOW SPEED OTIS ELEVATOR MOTOR AND BRAKE

adjustments. The brake is held on by springs and released by a brake magnet which is provided with a shunt winding of such proportions that its self-induction causes an appreciable lag of time between the closing of its circuit and the release of the brake shoes. Thus while the armature and brake circuits are closed practically at the same time, sufficient time elapses to build up the full motor torque before the brake releases. When the current is shut off, there is again sufficient lag to permit the motor to come practically to a stop by dynamic brake action before the brake sets. Together with the advantage of stopping almost entirely by dynamic braking

is the fact that the wear on the brake shoes is a minimum and when once set, the brake rarely requires further adjustment.

DIAGRAM OF CONNECTIONS

A schematic diagram of the connections for controlling the operations of these elevators is given in Fig. 11. The field connections are from the + main, through *8*, resistance *R*, magnet *H*,

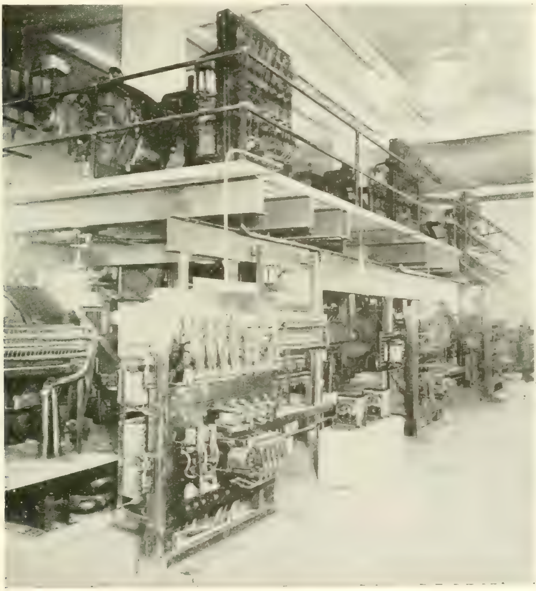

FIG. 8—GENERAL VIEW IN ONE OF THE MOTOR AND CONTROL ROOMS

the motor shunt field and point *10* on the — main. The series starting resistance is in two parts, one operated automatically by the accelerating magnets and the other controlled by the master switch. Hatchway switches shown at the left in the diagram at *a*, *b*, *c*, *d*, *e*, and *f*, *g*, *h*, *k*, *l*, are placed one group at the bottom and the other at the top of the shaft. Fig. 10 shows a photograph of such a switch. They are operated by a long cam placed on the car, which strikes the switch rollers and thus opens their contacts and brings

the car to rest automatically at the terminals of the car travel, even though the operator retains the master switch in the running position.

The several magnets on the control board and their purpose are as follows:—

The Main Line Switch, A, carries the current for all parts of the elevator mechanism except the motor field. Its exciting coil is energized by a circuit from the + main, through *8*, secondary fuse, contacts *161* and *162* of magnet *H*, switch *n*, switch *m*, contacts *103* and *104* of a governor driven by the car, the upper con-

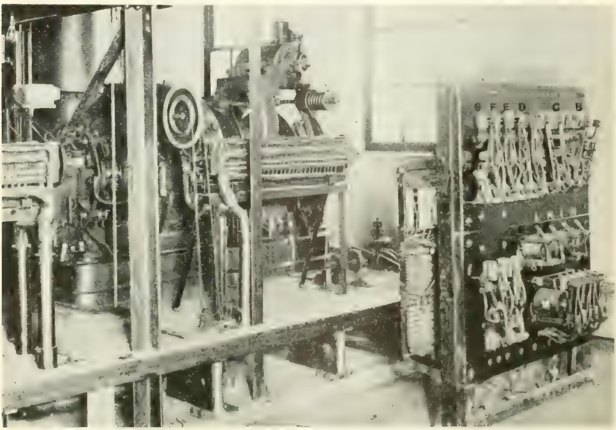

FIG. 9—VIEW OF MOTOR, SWITCHBOARD, POSITION INDICATOR MECHANISM, ETC.

Control board lettered to correspond with wiring diagram. Contactor for position indicator shown in center of illustration in front of motor. Travel indicator shown in background at left. Contacts numbered 202 and 203 in the wiring diagram, are at the top of the brake magnet.

tacts of hatchway switch *l*, lower contacts of hatchway switch *e*, coil of switch *A*, upper contacts of hatchway switch *e*, lower contacts of hatchway switch l, *106*, *107*, and out to the – terminal. It will thus be seen that the circuit through the coil of the main line switch *A* is broken, the switch dropped and the feed wires to the motor interrupted when any of the following contacts are separated:—

1—Contacts *161* and *162* of switch *H*—The coil of this swtich is in series with the shunt field current. On failure of this supply from whatever cause the motor stops.

2—Contacts of switch *n*—This switch is a safety device placed close to the master switch. In case of emergency the elevator operator may open it and thus open the main switch *A*.

3—Contacts of switch *m*—This switch is placed on the bottom of the car and operated by the car safety, a device which locks the elevator car to the guides in case of excessive speed through breakage of cables or any other cause. This safety device is in turn controlled by the governor, which is driven by an endless rope attached to the elevator car. If, therefore, the car attains a speed (about 750 feet per minute), sufficiently high to cause the car safety to act, the contacts of switch *M* are interrupted thus stopping the motor.

4—*Governor contacts*—The governor has two fixed contacts, *101* and *103*, and two movable contacts, *102* and *104*. When the car speed increases above normal, first contacts *101* and *102* close, thus short-circuiting part of the shunt field resistance and thereby slowing down the machine. If the speed keeps on increasing, contacts *103* and *104* break the circuit through the coil of the main line switch and stop the machine.

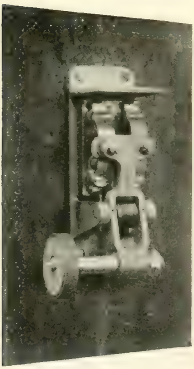

FIG. 10—HATCHWAY SWITCH

5—The contacts of hatchway switches *l* and *e*, operated by a cam attached to the car, positively limit the travel of the car up and down. Under normal conditions the elevator will automatically come to a stop when the cam on the car opens switch *k* at the top or *d* at the bottom. If, however, for some reason motion continues, the opening of the contacts of switches *l* or *e* will open the main switch *A* and at the same time contacts *15*, *16*, *17*, *18* will be closed, causing a very strong dynamic breaking effect by short-circuiting the armature through *65* to *66* of the *Armature Shunt Resistance*.

Reversing Switches B and C—Each of the switches *B* and *C* has two coils, the lower one a shunt coil and the upper a coil in series with the armature. These coils work in opposition to each other having, however, separate paths for the two magnetic fluxes. Thus when the shunt coil of *B* is energized *B* closes top contacts *21*,

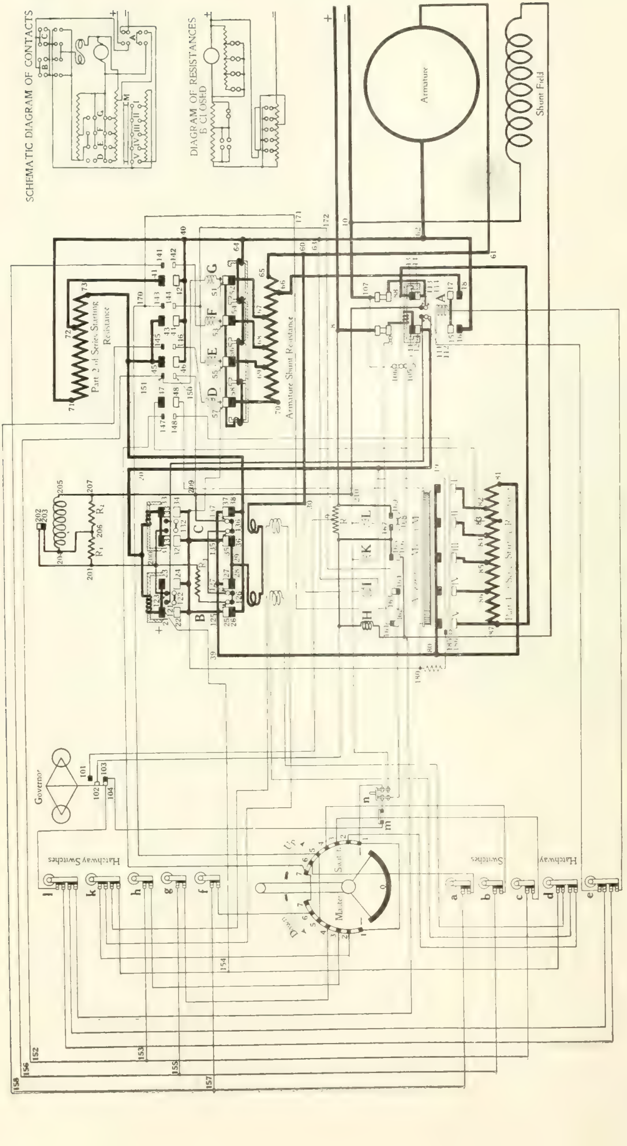

FIG. 11—SIMPLIFIED DIAGRAM OF CONNECTIONS OF POWER, CONTROL, MASTER SWITCH AND BRAKE CIRCUITS

Nos. *0-7*, master switch; *8-99*, power circuits; *100-199* control circuits; *200* to *210* brake circuits.

Heavy lines indicate main current carrying wires; medium weight lines, power carrying wires of small capacity, and light lines, control wiring. Stationary contacts are indicated solid and movable contacts in outline.

22, 23, 24 and opens bottom contacts *25, 26, 27, 28*, and the course of the current will be from *8* on the + terminal, down to contacts *11* and *12* of the main line switch, *19* and *20* contacts *21, 22, 23, 24*, of switch *B*, contacts *35* and *36* of switch *C, 29*, series coils of switches *B* and *C, 30, 60, 61*, armature, *62, 63, 64, 40, 71, Part 2 of Series Starting Resistance, 73*, contacts *38* and *37* of switch *C, 39, 80, 81, Part 1 of Series Starting Resistance, 87*, contacts *13* and *14* of main line switch to — terminal. At the same time a circuit parallel with the armature is made, branching off at *60*, to portion between *65* and *67* of *Armature Shunt Resistance*, contacts *52, 51, 53, 55, 57*, of switches *G, F, E, D, 61* and back to armature. It will be seen that when switch *B* operates, the current passes through the top contacts of switch *B* and the bottom contacts of switch *C*.

The effect of the series coils on these switches is as follows:— Suppose the shunt coil of *B* to have been energized and as a consequence its top contacts made and its lower contacts opened. On account of the motion of the magnet plunger to its extreme position under the influence of the shunt coil the energizing of its series coil, which occurs a little later, following the closing of the contacts, has little effect in opposing the first named. However, as switch *C* remains in the off position without excitation in its shunt coil its plunger remains in such a position that the flux generated by its series coil has maximum effect tending to press contacts *35* and *36*, and *37* and *38* strongly together for good contact. When the elevator is stopped the current through the shunt coil of *B* is interrupted, but the current through its series coil is not broken until a moment later when the top contacts break. While thus the effort of the shunt coil ceases, the effort of the series coil assists the weight of the switch armature to return the switch to its off position, thereby securing a quick break of the top contacts. For the reason that the top contacts of the reversing switches *B* and *C* make and break the main current they are arranged two in parallel.

The reversing switches also control the brake which is kept normally on by springs. When, for instance, *B* operates, contacts *121, 122, 123*, make and *125, 126, 127* break. The current goes from the + terminal, contacts *11, 12* and *112, 111* on switch *A*, contacts *121, 122, 123* of reversing switch *B, 200, 201*, contacts *202* and *203* of a switch mechanically operated by the brake magnet, *204*, brake coil, *205, 207, 210*, contacts *113, 114*, of the main line switch to the — ter-

minal. As a consequence the brake releases and in doing so breaks contacts *202* and *203*, which connects resistance R_1, in series with the brake coil, thus reducing the current in the coil and preventing overheating. At the same time R_2 remains in parallel with the brake coil. When switch B drops out, the current through the brake coil is interrupted but a self-induced current is maintained over resistance R_2, with the tendency to retain the brake released. When finally switch B returns to its off position contacts *125*, *126* and *127* make again and parallel R_2 over *206*, resistance R_1, *201*, resistance R_3 contacts *125*, *126*, *127*, contacts *135*, *136*, *137*, to *209* and *207*, with the effect of maintaining the current through the coil. The current quickly weakens to the point where the brake plungers separate and allow the brake to set, but shortly before this takes place contacts *202*, *203* close again, thus cutting out resistance R_1. This practically short-circuits the brake coil as resistance R_3 is very small. The result is a maintenance of the induced currents in the brake coil, which exercises a retarding effect on the moving magnet cores, so that the brake shoes gently grip the brake pulley without shock. By means of the resistance R_2, and R_3, the time lag between the interruption of the brake coil current and the setting of the brake may be regulated within limits.

Switch C is identical with switch B except that B controls the down motion of the car, while C controls the up motion.

Speed Switches D, E, F, G—These switches are controlled by the master switch. Switch G is designed to operate first, closing contacts *11* and *12*, cutting out portion *71* to *72* of *Part 2 of Series Starting Resistance*, and breaking contacts *51* and *52*, thereby inserting portion *67* to *68* of the *Armature Shunt Resistance* in the circuit across the armature. G also operates the secondary contacts *141* and *142*, which are part of the circuit of the coil of switch F, so that F cannot be energized unless switch G has closed. When F operates, the closure of contacts *13* and *14* short-circuits all of *Part 2 of Series Starting Resistance* and the opening of contacts *53* and *54* inserts portion *68* to *69* of the *Armature Shunt Resistance*. The closure of its secondary contacts *143* and *144*, which are part of the energizing circuit of switch E, permits the operation of this switch only when F has closed, except under certain special conditions which are discussed later.

The closing of contacts *45* and *46*, through the operation of switch E, has no further effect, these contacts being in parallel with

43 and *44* respectively. The opening of *55* and *56* inserts additional resistance in the armature shunt circuit. The right hand set of secondary contacts *145* and *146* of switch *E* are to prevent the energizing of *D* unless *E* has operated. The purpose of the left hand secondary contacts *150* and *151* is indicated in a later description of magnet *I*.

The operation of *D* breaks contacts *57* and *58*, thereby opening the armature shunt resistance. It also closes contacts *47* and *48* thus closing the circuit of the *Accelerating Magnet M*, while the secondary contacts *147*, *148* allow the insertion of resistance into the shunt field circuit by the master controller.

Fast and Slow Speed Switch L is energized simultaneously with the making of the main current, receiving current from contacts *22*, *24* or *32*, *34* via *180*, *185*, coil *L*, *210*, *113*, *114* and out to the — terminal. As a consequence contacts *167*, *168*, *169* make, thus short-circuiting the shunt field resistance *R* and permitting the motor to start up with maximum strength of shunt field.

Accelerating Magnet M automatically controls *Part 1 of Series Starting Resistance* and comprises five switches, each having its own magnetic circuit but all energized by a single coil. This coil is energized when switch *D* closes contacts *47* and *48*, receiving current from *180*, which connects with the upper moving contacts of the reversing switches, *Accelerating Magnet M*, contacts *48* and *47* of switch *D*, and point *83* of *Part 1 of Series Starting Resistance*. It is, as may be seen, in parallel with the armature, and subject to its counter e.m.f. The switches are adjusted so that at a certain counter e.m.f., *I* operates and as the motor accelerates *II*, *III*, *IV*, and *V*, each successively cut out a step of *Part 1 of Series Starting Resistance*. On the operation of *V* all of the starting resistance is cut out. At the same time the secondary contacts *185* and *186* are made, which permits the short-circuiting of coil *L*, in as much as the current, which originally passed through coil *L*, will be diverted to go from *185* to *186*, contacts *148* and *147* of switch *D*, contact *7* of the *Master Switch* and out to the — terminal in case the switch is in either of its extreme positions. With these conditions the machine runs at maximum speed. The *Accelerating Magnet M* cannot be energized unless switch *D* has operated. This

safety feature prevents the cutting out of all the series resistance, i. e., placing the motor directly across the line, before the armature shunt resistance is opened.

Load Switch I is in parallel with the armature, being connected to the armature wires at *30* and *63*. It is, therefore, also subject to the motor counter e.m.f. and will consequently not separate its contacts *163* and *164* unless the motor has attained a certain speed. Also, if the motor speed drops below a fixed minimum the switch will drop out, making contacts *163* and *164* again. The functions of this switch will be explained later.

Safety Switches H and K—Switch *H* is in series with the shunt field and as explained previously, it will break its contacts *161* and *162* in case of failure of the shunt field current. The breaking of contacts *161* and *162*, results in the dropping of the main line switch and stopping the machine.

Switch *K* is connected directly across the line. In case of excessive potential (20 percent above normal) it operates, making contacts *165* and *166*, thus short-circuiting magnet *H*. The latter consequently drops, breaking contacts *161* and *162* and stopping the machine in the manner above described.

With the functions of the several magnets as explained above, the operation of the elevator by means of the master switch is now as follows:—Contact 1 of the *Master Switch* is connected to the — side of the line, via the right hand contacts of emergency switch *n*, *210*, contacts *113*, *114* of the main line switch *A* and since by moving the master switch handle, for instance, in the direction of the *Down* arrow contacts *2*, *3*, *4*, *5*, *6*, *7* at the right are successively connected with *1*, through segment *o*, the currents may be traced from these contacts to the + side of the line. Thus when contact *o* engages point *2*, the path of the current will be *1*, *2*, lower contacts of hatchway switch *d*, shunt coil of reversing switch *B*, back to upper contacts of hatchway switch *d*, thence to *154* and contact *21* of reversing switch *B* which is connected with the + side of the line. This energizes the coil of switch *B*, which in operating makes the motor connections and lifts the brake.

Further motion of the *Master Switch* brings contactor *o* in connection with point *3*, and the current may be traced via hatchway switch *c*, *153*, *152*, *151*, coil of switch *G*, to contact *34*, which upon the operation of either reversing switch is in connection with the + terminal. The operation of *G* cuts out a step of the armature

series starting resistance and inserts additional resistance in the armature shunt resistance, thereby speeding up the motor. In the same manner another increase of speed occurs, when *F* is energized following the energizing of point *4* by the *Master Switch* via *1, 4,* hatchway switch *b, 155, 156* contacts *141* and *142* of switch *G,* coil *F* and contact *34* on the reverse switches.

When the *Master Switch* makes contact at point *5*, the connections result in the energizing of speed switch *E* with a corresponding increase in the elevator speed. In this case the current does not run through any of the hatchway switches.

Switch *D* is energized when the *Master Switch* is moved to make contact at point *6*, the path of the current being *6*, hatchway switch *a, 157, 158,* contacts *145* and *146* of switch *E,* coil *D,* etc. With the operation of *D*, the armature shunt resistance is opened, the *Accelerating Magnet M* is placed across the armature and a further acceleration occurs automatically through the gradual cutting of *Part 1 of Series Starting Resistance.* Finally with the *Master Switch* in the extreme position segment *o* makes contact with point *7*, thus short-circuiting in the manner already explained, the fast and slow speed magnet *L*, which in dropping out inserts the resistance *R* in the shunt field and brings the motor to maximum speed. This current also does not pass over the hatchway switches. Moving the *Master Switch* handle in the direction of the *Up* arrow, causes the magnets to act in the same manner, except that reversing switch *C* instead of *B* operates, causing the motor to run in the opposite direction. Also it will be seen that the currents, operating the switches *C, G, F, D,* in this case take their paths over the upper hatchway switches, *k, h, g* and *f*.

In stopping at the floors the *Master Switch* handle is placed in the central position and the switches return to their off position in the reverse order from which they operated at starting. All elevators are provided with a device that brings the machine automatically to rest at the upper and lower terminals of the car travel, independent of the operating device.

Suppose the elevator is going down and the operator retains the *Master Switch* in the full speed down position; a cam placed on the car will, when near the bottom landing, successively open the lower group of the hatchway switches, with the following results. The breaking of the contacts of switch *a* drops magnet *D*. The breaking of its contacts *47, 48*; *147, 148* results for the one part in the interrupting of the circuit through the *Accelerating Magnet*

M inserting *Part 1 of Series Starting Resistance* and for the other part in breaking the short-circuit around the fast and slow speed magnet *L* through the breaking of contacts *185*, *186*, of the accelerating switch. *L* again becomes energized and in attracting its armature, making contacts *167*, *168*, *169*, short-circuits the field resistance *R*. The making of contacts *57* and *58* on switch *D* results further in reëstablishing the *Armature Shunt Resistance 65* to *70* and the effect of the three operations slows down the motor. A little later the cam on the car opens the contacts of hatchway switch *b*, dropping switch *F*. Since the secondary contacts *143* and *144* of this switch control switch *E*, under ordinary circumstances *E* will drop also. The result is that a portion of *Part 2 of the Series Starting Resistance* is added to the armature circuit, and the closing of the bottom contacts *53*, *54*, and *55* and *56*, short-circuits the portion between *68* and *70* of the *Armature Shunt Resistance*, thereby exercising a considerable slowing down effect. The opening of the contacts of hatchway switch *c* drops switch *G*, with the result that with the breaking of top contacts *41*, *42*, the entire series resistance is placed in the armature circuit, while the making of contacts *51*, 52, reduces the armature shunt resistance to portion *65* to *67*.

The further motion of the elevator car causes the cam to engage the hatchway switch *d*, which drops reversing switch *B*, breaking the armature circuit and leaving the motor subject to the dynamic brake action due to the shunt across the armature with resistance *65* to *67* and a maximum strength of field. A little later, due to the lag between the action of reversing switch and brake, the brake sets and the elevator, under ordinary circumstances, stops. Should, however, its motion continue for some reason, the opening of hatchway switch *e* occurs, followed by the dropping of main line switch *A*, which in making its lower contacts *15*, *16*, *17*, *18*, reduces the armature shunt resistance still further to the portion *65* to *66*, thereby exercising a heavy dynamic braking effect.

If the elevator still continues to travel it will engage the buffer under the car, relieving the traction on the motor sheave, and positively stopping the car. It will be noticed that the hatchway switches, which slow down the elevator, namely, *a*, *b*, *c*, at the bottom and *f*, *g*, *h*, at the top, have double contacts, while those more important and stopping the motor, namely, *d*, *e* and *k*, *l*, at bottom and top respectively, break the circuit at four points.

The series starting resistance is not proportioned to the maximum elevator load, but to the average. That is, the two parts of the starting

resistance in series will admit sufficient current to the motor to start an average load, but the maximum load can only be started when *Part 2* is cut out. For this reason, the series starting resistance is split in two parts, of which one is under control of the operator. Since, however, when the car reaches the terminal landing and opens the several hatchway switches, all of the magnet switches successively drop into their off position, beyond the further control of the operator, and the reinsertion of the resistances as outlined above may stall a heavy load before the terminal landings are reached. By heavy load is meant a heavy load on the motor. Since the counterweight is approximately 1 100 lbs. (for the passenger machines) heavier than the car, the greatest loads on the motor occur on the up motion with the maximum live load in the car and on the down motion with empty car. In order to prevent stalling, a device operated by the load magnet *I*, is provided which prevents the motor from slowing down below a certain limit, when the car successively engages the hatchway switches. If the car slows down below that limit, switch *I*, whose coil is energized by the counter e.m.f., drops out, permitting contacts *163*, *164*, to close.

Considering, therefore, the case of a heavy load on the motor, the operator retaining the master switch in the full down position and the cam on the car striking the lower hatchway switches:—First, the opening of *a* drops switch *D*, the opening of *b* drops *F* and when the load is average, also *E*, due to the opening of the secondary contacts *143*, *144*. If the load is heavy, the resulting slow down is too much, causing the load magnet *I* to drop out and close contacts *163*, *164*. This results in by-passing contacts *143*, *144*, so that *E* will remain energized by a circuit via *1*, *5*, on the *Master Switch*, *170*, *171*, contacts *164* and *163* of switch *I*, *172*, coil *E*, contact *37*, which is connected to the + side of the line if either of the reversing switches is in operation. With a heavy load, therefore, *E* remains energized and as its secondary contacts *150*, *151*, stay closed, magnet *G* receives current from contact *37*, coil *G*, secondary contacts *150*, *151* of switch *E*, *209*, *210*, contacts *113*, *114* of main line switch and out to the — terminal. When, therefore, the cam on the car engages hatchway switch *c* in case of a heavy load, switch *G* nevertheless remains closed, so that in such a case, of the four switches *D*, *E*, *F*, *G*; *D* and *F* drop out and *E* and *G* stay in. The result is that all of *Part 2 of Series Starting Resistance* remains cut

out, with the resistance of 65 to 68 shunted across the armature, whereby sufficient potential and current is supplied to the motor to prevent stalling or undue slowing down.

Each of the elevators has a trip recorder, a travel recorder, whereby the total travel of the car in feet may be recorded, and a wattmeter. Daily readings of these instruments are taken, and, through the courtesy of Mr. Evans, Superintendent of Power, the following average performance during the month of October, 1910, is published. The average travel of the low rise passenger elevators, which make all stops between first and fourteenth floors was 432 miles at a power consumption of four kw-hr. per car mile. The average travel of the high rise passenger elevators, which make all stops above the fourteenth floor, was 875 miles at an average current consumption of 2.85 kw-hr. per car-mile. The marked difference in the power consumption between the high and low rise elevators is due to the greater number of stops per mile of travel of the latter. The travel and trip recorders also form a convenient method of checking the over-run of floors.

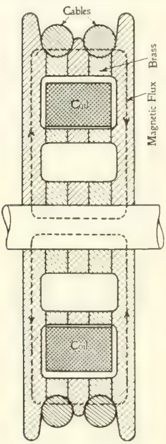

FIG. 12—MAGNETIC SHEAVE

The freight elevator travels from sub-basement to twenty-fifth floor, a distance of 351 feet. This machine is designed for an ordinary duty of 3 000 lbs. at a speed of from 450 to 500 feet per minute, and a maximum lifting capacity of 5 000 lbs. at slow speed. When lifting this extreme load, the car is operated by a separate master switch located at the machine, the operator receiving bell signals from an attendant in the car. The master switch permits the operation of the elevator at slow speed only and the additional traction required to lift the heavy load is obtained by employing a magnetic traction sheave, and by additional counter weight attached to the ordinary weight. The principle of the magnetic sheave is shown in Fig. 12. It will be seen that the driving sheave consists of alternate sections of cast iron and of non-magnetic material. This forces the magnetic flux to pass through the cables, thus attracting them tightly to the cast iron and increasing the friction. When lifting the extreme load the elevator is equipped with an additional magnet brake in parallel with the ordinary brake.

SOME CHARACTERISTICS OF TUNGSTEN LAMPS

J. FRANKLIN MEYER

THERE are two general types of incandescent electric lamps, those made of some metal and those made of carbon or metallized carbon. The metal filament lamps of commerce are of two kinds,—lamps having filaments of tungsten and lamps having filaments of tantulum. Only tungsten lamps are here considered.

Some of the desirable qualities of a material for a lamp filament are:—

1—Very high melting point so that it can be operated at high temperatures.

2—Low vapor tension so that it can be heated to a high temperature in a vacuum and not evaporate readily.

3—High specific resistance so that filaments are not too long or too small in cross section.

4—Stable resistance and positive temperature coefficient.

5—Mechanical strength.

6—Selective emission in the visible spectrum.

These conditions are met most fully at the present time by the tungsten lamp filament. Tungsten is an element, just as are copper and platinum, being found in nature in the minerals Schelite, Huebnerite and Wolframite. The crude oxide from which tungsten filaments are made is received by lamp manufacturers in the form of a heavy yellow powder. The refined metal is white, and very hard. It is also very heavy, having an atomic weight of 183, and a specific gravity of about 18.7, which may, however, be considerably increased by various methods of filament manufacture, so as to be as high as 20.2. Its specific heat is 0.0358, its heat of combustion about 1047 calories, and its melting point above 2700 degrees *C.*, more than 1 000 degrees higher than platinum. Its specific resistance varies from 6.9×10^{-6} to 5.2×10^{-6} ohms, or about three and one-half times that of copper, the exact value depending on the method of treatment.

As a result of its lower specific resistance the filament in a tungsten lamp is very much longer than the filament of a carbon lamp of the same rating. Since the metal tends to become soft when incandescent, and will fuse instantly to the glass of the sup-

ports or bulb, if allowed to come into contact, the filament must be supported by anchors at both ends of the lamp. The arrangement of filaments on a spider in a tungsten lamp with respect to reference planes in the three dimensions is shown diagramatically in Fig. 1.

Tungsten filaments are adaptable for use in all types of lamps and at all commercial voltages. Sign lamps consuming 2.5 watts at 10 volts, and 500 watt lamps at 110 volts are on the market. In the 2.5 watt sign lamp, the filament is about two inches long, while in the 500 watt lamp the filament is 60 to 70 inches in length, depending upon the voltage. The diameters of filaments in different types of lamps also vary widely. Filaments made for 15 watt 110 volt lamps are only 0.0008 to 0.0009 inch in diameter or considerably smaller in diameter than human hair, while filaments in lamps used for series street lighting are 0.010 to 0.015 inch in diameter and even larger. The dimensions of a filament for any wattage and voltage are determined by the general condition that the power supplied to the lamp is radiated from the filament in the form of radiant energy, that is heat and light. A certain percentage of the power supplied to the filament is always lost by the cooling effect of anchors and lead-in wires. This varies with the construction of the lamp, being dependent upon the number of anchors used and the material and size of the anchors. If, however, this loss is neglected, the diameter of a filament necessary for any given current can be readily calculated.*

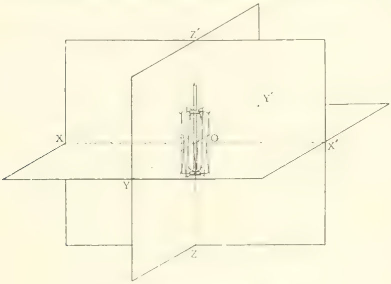

FIG. 1—REFERENCE PLANS
For light distribution curves.

*Let S = Surface of a filament; r = Resistance of filament; d = Diameter of filament; l = Length of filament; v = Voltage supplied; i = Current, and $w = iv$ = Wattage of the lamp considered. Then since the total energy supplied is radiated from the filament, we can write: $iv = i^2r \propto S$. But $S \propto ld$, and $r \propto \frac{1}{d^2}$. We have then $i^2 \frac{1}{d^2} \propto ld$, or $i^2 \frac{1}{d^2} = Kld$. Therefore $d = k\, i^{\frac{2}{3}}$, where k is a constant, depending on the characteristics of the filament used. From this general formula, knowing the value of the constant k, which is determined by experiment on various types and kinds of lamps, it is possible to calculate the diameter of filament necessary for a lamp of any wattage and voltage.

Tungsten, being a metal, has a positive temperature resistance coefficient, while for carbon the coefficient is negative, that is, as the current in a tungsten filament rises under increasing voltage, the temperature of the filament increases and its resistance increases.

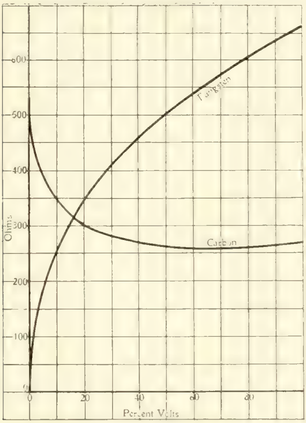

FIG. 2—CURVES SHOWING COMPARATIVE RESISTANCE OF CARBON AND TUNGSTEN LAMPS

Curves showing the variation of resistance with increasing voltage in carbon and in tungsten lamps are given in Fig. 2, while the relation of the resistance and current in a tungsten filament is given in Fig. 3. As shown, the resistance of the tungsten filament is from 11 to 13 times as great when hot as when cold. This difference causes the well known overshooting of tungsten lamps. As a result of the positive temperature coefficient, variation of voltage on a tungsten lamp has a smaller effect on the current and consequently on the candle-power than it has on carbon lamps. This is an important point in the operation of incandescent lamps. A one percent increase in voltage gives approximately the following percentage increase in current in carbon and tungsten lamps:—Tungsten, 0.60 percent; untreated carbon, 1.30 percent; treated carbon, 1.05 percent; metallized carbon, 0.75 percent.

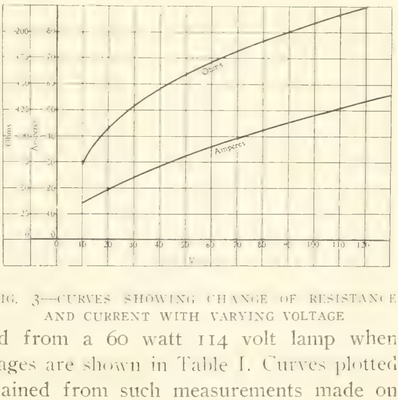

FIG. 3—CURVES SHOWING CHANGE OF RESISTANCE AND CURRENT WITH VARYING VOLTAGE

The results obtained from a 60 watt 114 volt lamp when burned at increasing voltages are shown in Table I. Curves plotted from average values obtained from such measurements made on

many lamps are called characteristic curves. Such curves are shown in Fig. 4, while Fig. 5 shows variation in wattage for a particular 60 watt lamp with increasing voltage.

Only a small percentage of the total power supplied to an incandescent lamp becomes available as light. Measurement made by different observers vary widely. The following table taken from a paper by Leimbach* gives the most recently determined values.

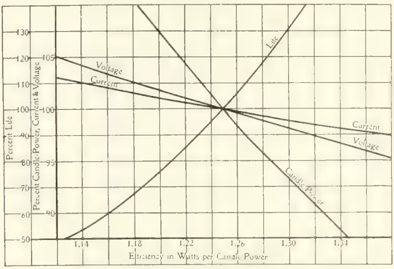

FIG. 4—CHARACTERISTIC CURVES OF TUNGSTEN LAMP

The two values approach equality as the amount of energy lost by convection and conduction is decreased. While the function of a lamp is the production of light for the purpose of illuminaton, as seen from Table II, only about 3.5 percent of the energy supplied to a tungsten lamp is radiated by the lamp as light. The quantity of light radiation from a lamp is measured in units of luminous flux called lumens. The intensity of the luminous flux is measured in candles. To make the relation of lumens to candles clearer an analogy may be used. Conceive a hollow sphere two inches in diameter to be fixed to the end of a small upright water pipe. The area of this sphere then is 4π sq. in. or 12.5664 sq. in. Imagine 1 000 small holes made in each square inch of the surface of the sphere. If now the incoming pipe be neglected, for the sake of symmetry, and weightless water is turned on, there will be a uniform flux of water outward from the surface of the sphere. From

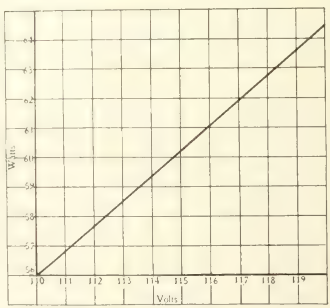

FIG. 5—CURVE SHOWING POWER CONSUMED BY TUNGSTEN LAMP AT VARYING VOLTAGES

*Leimbach: Elek. Tech. Zeit., 1911, p. 266

each square inch of surface there will be 1 000 similar streams of water flowing, all diverging from the center of the sphere. The intensity of this flux of water will be equal in all directions, and

TABLE I—RESULTS OBTAINABLE BY BURNING A 60-WATT, 114-VOLT LAMP AT VARIOUS VOLTAGES

Volts v	Amperes i.	Ohms. $R=\frac{v}{i}$	Watts. w=vi	Candles c	Watts per Candle. $wpc=\frac{w}{c}$
10.0	0.140	71.4	1.40		
15.0	0.159	94.3	2.38		
20.0	0.187	107.0	3.74		
25.0	0.213	117.0	5.33		
35.0	0.261	134.0	9.13		
50.0	0.321	160.0	15.6		
60.0	0.356	168.0	21.3		
75.0	0.407	184.0	30.5	9.95	3.05
85.0	0.437	189.0	37.4	16.4	2.27
95.0	0.466	202.0	44.2	24.6	1.78
105.0	0.495	211.0	52.0	36.0	1.44
110.0	0.509	217.0	56.0	42.2	1.33
112.0	0.514	218.0	57.5	45.0	1.28
114.0	0.520	220.0	59.4	48.0	1.23
116.0	0.525	220.0	61.0	53.0	1.15
118.0	0.530	221.0	62.5	57.8	1.08
120.0	0.535	222.0	64.5	60.1	1.07

may be chosen as unit intensity and given a name. Such a source radiating *light* flux with unit intensity—one candle—would give forth unit flux—one lumen—through each unit solid angle. There

TABLE II—PERCENTAGE OF ENERGY INPUT AVAILABLE AS LIGHT

Type of Lamp.	Energy radiated as light ÷ Total energy radiated	Energy radiated as light ÷ Energy supplied
Carbon Lamp	2.85	1.75
Tantalum Lamp	4.26	2.75
Tungsten Lamp	4.63	3.50

are 4π or 12.5664 unit solid angles around the sphere. The total flux is, therefore, 4π or 12.5664 lumens. If all the holes in two square inches of the surface are closed, everything else remaining

as before, then there are only 10.5664 units of flux and the flux is no longer uniform. Again, a reflector placed so as to change the direction of part of the flux, would not change the total flux but would change its intensity in some directions.

In measuring the light of a lamp, units of flux and intensity are necessary. As previously stated, amount of light is measured in units called lumens and intensity of light flux in candles. Candle-power in any direction can be increased by reflectors and lenses, but flux of light from a lamp is independent of all accessory de-

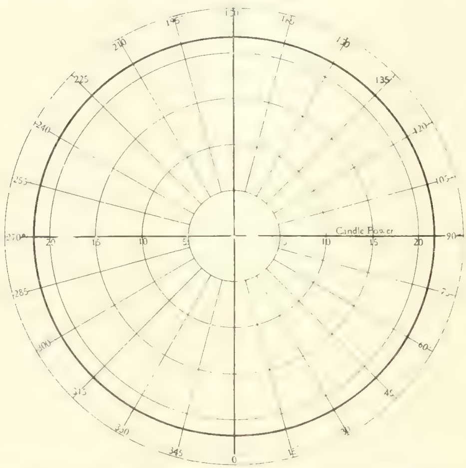

FIG. 6—HORIZONTAL DISTRIBUTION CURVE OF TUNGSTEN LAMP

vices. The number of lumens given by a particular lamp is, therefore, of more importance than the number of candles intensity in any given direction.

The intensity of a source of light usually varies with the direction from the source and it is therefore necessary to designate the direction in which any lamp's intensity in candles is measured. The mean horizontal candle-power of a lamp is the mean of the values of the intensity measured in all directions in a horizontal plane passing through the optical center of the lamp. In Fig. 1 is shown a

diagram of a lamp, the optical center of which is at the point O. If now the candle-power of the lamp be measured for each degree measured from the axis OX in the plane $O\ X\ Y'\ X'\ Y$ and the mean of all these values calculated, there is obtained the mean horizontal candle-power of the lamp. This horizontal candle-power is the candle-power ordinarily meant when we speak for example of a 32 candle-power lamp and is obtained in practical photometry by rotating the lamp about a vertical axis rapidly enough to prevent flickering while its candle-power is being

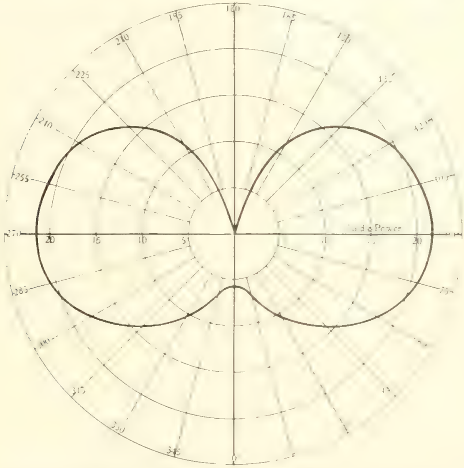

FIG. 7—VERTICAL DISTRIBUTION CURVE OF TUNGSTEN LAMP

measured. If, however, the candle-power is measured at various angles in the horizontal plane and these values are plotted as distances from a center, a curve drawn through the points so obtained will be the horizontal distribution curve for the lamp. Such a curve for a tungsten lamp is shown diagrammatically in Fig. 6. Due to the filament arrangement in a tungsten lamp, the horizontal distribution curve is approximately a circle.

If the candle-power of the lamp is determined at various angles, say for every five degrees measured from the ZZ' axis, as shown in Fig. 1, and a polar curve plotted, the vertical distribution

curve is obtained. Such a curve is shown in Fig. 7. The candle-power is zero in the direction of the base of the lamp, all the light being cut off by the base. A tungsten lamp being nearly symmetrical axially, the distribution curve in all vertical planes is the same.

The mean spherical candle-power of a lamp is the mean of the intensities in all directions from the lamp. It is the intensity of a source giving the same total amount of light as the lamp in question, but radiatng its light equally in all directions. The mean spherical intensity is difficult to measure directly and its calculation from distribution curves is not simple. As a result of these difficulties commercial photometric measurements on lamps are usually measurements of mean horizontal candle-power. The mean spherical candle-power of a particular type of construction being once determined, the ratio of the mean spherical candle-power to the mean horizontal candle power is a constant of much value. This ratio is called the spherical reduction factor and for tungsten lamps is approxi rately 0.78 for the 100 volt grade of lamps, and 0.79 for the low voltage lamps. By multiplying the mean horizontal candle-power by the reduction factor, the mean spherical candle-power is readily obtained.

THE LIGHTING OF SMALL OFFICES

C. E. CLEWELL

A NUMBER of small offices located throughout a large works have recently been provided with tungsten illumination. In this connection several problems have arisen in determining the most suitable size, number and arrangement of the lamps, which are explained in the following paper. At the outset it was agreed that the lighting should be such that any changes which might be made in the arrangement of desks or files would not require a re-adjustment of the lamps. Hence, satisfactory lighting in all parts of each office was the starting point. The offices were usually long and narrow; they differed in shape and in size, and the ceiling height ranged from eight to 13.5 feet.

At first sight the lamps as installed in some of the offices appear very close together and the number unnecessarily large, but there was a definite reason for the arrangement selected in each case, as it was the most suitable for meeting the condition of uniform illumination.

Althought this article refers specifically to certain factory offices, it will be noted that the principles involved apply generally to office lighting where the sizes of the rooms and the general requirements are similar to those which are taken up in this article.

ELIMINATION OF DROP LAMPS

In lighting any small square office sufficient light can, in general, be obtained by placing one large lamp at the center of the room. In like manner a long narrow office can be furnished with a sufficient quantity of light by one row of lamps down the center. However, unless the office is very small, while there may be a sufficient quantity of light, it will nearly always be poorly distributed that is, desks located directly under the lamps may be sufficiently or even over-lighted, while those located along the walls and sides of the room will generally be poorly lighted, and will usually require drop lamps. This will be especially the case where side desks are used, due to the shadows cast upon the desks by those using them.

In lighting the offices here referred to, one of the main purposes was to avoid the use of individual drop lamps, by furnishing a light

equally satisfactory in any part of the room. This end was sought by taking the necessary candle-power (or the equivalent watts) required to furnish sufficient light and, by dividing this candle-power by the proper number of lamps required for a suitable arrangement, to determine the size of lamps which, when properly spaced, will insure that a desk placed at any point in such an office will be satisfactorily lighted.

RANGE OF THE NUMBER OF LAMPS FOR EACH OFFICE

As can be seen from the foregoing the possible number of units ranges from one large lamp at the center of a square room, or one row of lamps down the center of a long narrow room, to a larger number of smaller lamps distributed over the ceiling for the purpose of supplying a uniform light on the entire working surface of the office. From experience in making other installations, the watts necessary to furnish a given quantity of light for a room of certain area can be closely determined.*

FIRST COST AS A FACTOR

After deciding on the necessary candle-power, and the equivalent energy expressed in watts, it is practically immaterial from the standpoint of energy consumption, whether this energy is utilized in the form of one large unit or many small units. On the other

*TABLE I—DATA FOR TUNGSTEN LAMPS WITH EFFICIENT REFLECTORS
(From the Journal, Vol. VI., 1909, p. 743.)

Type of Service	Watts per Square Foot
Drafting room	1.00 to 1.25
Factory, general illumination only, where additional special illumination of each machine or bench is provided	0.40 to 0.60
Factory, complete illumination	1.00 to 1.25
Hotel, halls	0.20 to 0.30
Hotel, guests' rooms	0.50 to 0.70
Hotel, parlors	0.40 to 0.50
Office, waiting or consultation room	0.40 to 0.50
Office, private office or board room (no individual desk lighting)	0.60 to 0.75
Office, general office or bookkeeping (no individual desk lighting)	0.90 to 1.20
Office, private or general (general illumination only where individual desk lighting will be used in addition)	0.30 to 0.45
Residence, halls	0.20 to 0.30
Residence, sleeping rooms	0.30 to 0.45
Residence, living rooms	0.50 to 0.75
Store, book, furniture	0.75 to 1.00
Store, light-colored fabrics, china, drug, jewelry, shoe, hardware, etc.	0.90 to 1.20
Store, dark-colored fabrics, clothing	1.20 to 1.50
Train Sheds	0.30 to 0.40
Warehouse	0.30 to 0.50

Note. Use larger watt per square foot values in above table when room has dark walls. Use smaller watt per square foot values when room has light colored walls.

hand, the first cost of the installation is affected by the number of units to be used as the first cost of the wiring is naturally somewhat increased if a greater number of outlets are provided for a given area. In view of the fact that the satisfaction of the light in any position of the room depends largely on the number of units and the way they are spaced, the use of a larger number of small units is often entirely warranted due to a crowded condition of desks in the office. This is particularly the case in factory offices where, in addition to crowded conditions, the desks are frequently shifted.

Furthermore the first cost is a charge that may be considered as spread over a long period of time, and as such is a factor of a lower order than is that of satisfaction. It may be stated that in one instance, where a certain office installation was contemplated, the first cost of installing a tungsten lighting system amounted to one-third of one percent of the wages paid the employees in these offices for one year. This was about the equivalent of the wages for one and one-half minutes per day, which means that the first cost of the improved lighting could be reduced to the equivalent wages of one and one half minutes per day for one year's time. The losses in time and efficiency due to poor light may be classed in values from perhaps one-half an hour to two hours per day, so that what might be considered as an economy in the installation of a system of low first cost giving inadequate lighting, becomes an extravagance, when compared with the losses of time involved by those using it.

THE SPACING DISTANCE OF LAMPS

After deciding upon the energy, expressed in watts, required to give a proper intensity of light, it becomes necessary to determine the size and spacing of the lamps to give uniform satisfaction in any part of the office. From extensive tests it has been found that for an office with a ceiling height of approximately 12 feet, the lamps should be spaced about 7.5 feet apart and should be spaced 2.5 feet from the walls to provide for desks placed directly against the walls.* In standardizing the spacing of lamps for all sizes of offices, a chart was devised giving the spacing distances for offices of varying widths.

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*For further information see "Notes on Office Lighting," by the author in the JOURNAL for May, 1910.

A study of this chart, Fig. 1, shows that the most difficult offices to light are those with a width of 10, 14 and 22 feet, and so on, namely at those points where the office is a little too wide

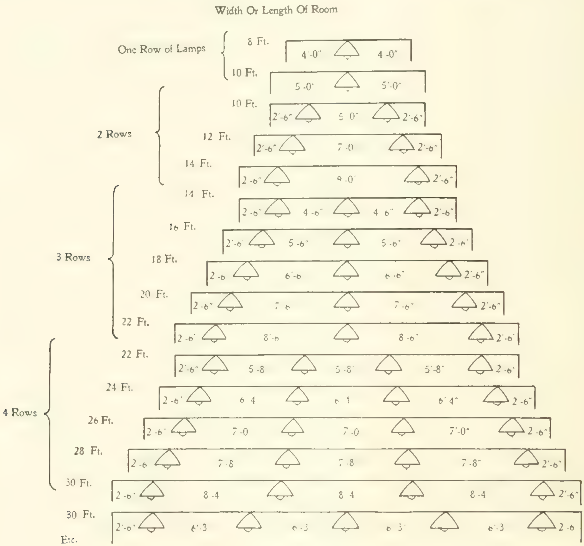

FIG. 1—CHART SHOWING THE SPACING DISTANCES OF LAMPS FOR VARIOUS SIZED OFFICES

The dimension to the left of each section indicates the width (or length) of the room.

for, say one row of lamps, as in the case of the 10 foot width and a little too narrow for two rows. For the purpose of tabulating the

TABLE II.—SPACING DISTANCES FOR OFFICE LIGHTING WHEN THE CEILINGS ARE ABOUT TWELVE FEET IN HEIGHT

Width (or length) of office.	Number of lamp rows,
Up to 10 feet	1 lamp at centre
10 to 14 feet	2 rows.
14 to 22 feet	3 rows.
22 to 30 feet	4 rows.
30 to 38 feet	5 rows.
38 to 46 feet	6 rows.

number of rows of lamps necessary for offices of all widths based on this chart, Table II was prepared, to show as nearly as possible the standard spacings as chosen.

As an illustration, assume an office 15 by 35 feet. From Table II it will be seen that three rows of lamps with five lamps per row are required. The general rule to be followed in using this table is: Space all lamps next to walls or partitions about 2.5 feet from the wall and so arrange the remaining lamps as to be equidistant from on another.

According to some rules the floor space should be divided up into small squares and one lamp located at the center of each square. This method has been tried, but it was found in some cases that the

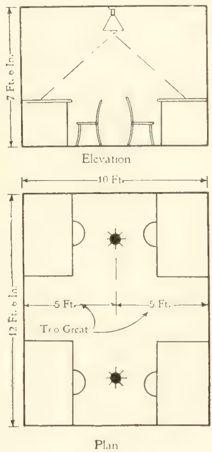

FIG. 2—ONE ROW OF LAMPS
Poor scheme if office is crowded with desks.

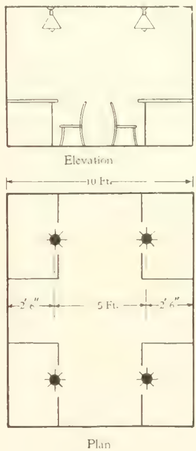

FIG. 3—TWO ROWS OF LAMPS
A good arrangement for an office of this size.

lamps nearest the walls were so far out that an additional row of lamps was necessary in order to take care of desks located directly against the wall. It has been found advisable to give each office careful study for the purpose of providing for desks or other work located against the walls, and particularly in cases where the workman faces the wall. If the lamps are located in the center of small squares, as called for by the rule referred to, the edge lamps will be located at a distance from the wall equal to one-half the spacing distance between lamps, which may be too great. In the offices

under consideration the lamps were often spaced less than half the spacing distance, from the sides of rooms, but not more than this distance. In general it is found that if the lamps are placed from two to three feet from the sides, desks located next to walls will be suitably lighted.

Regarding certain offices which appear overlighted, it may be

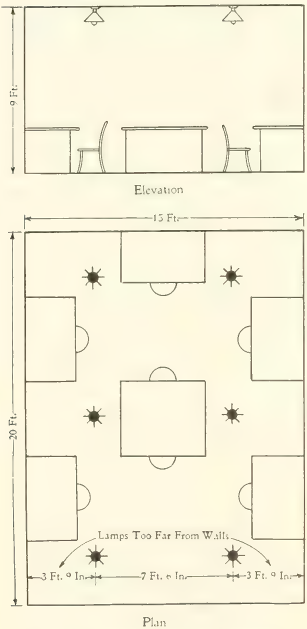

FIG. 4—TWO ROWS OF LAMPS
These lamps are the proper distance apart. but too far from sides of room to take care of side desks.

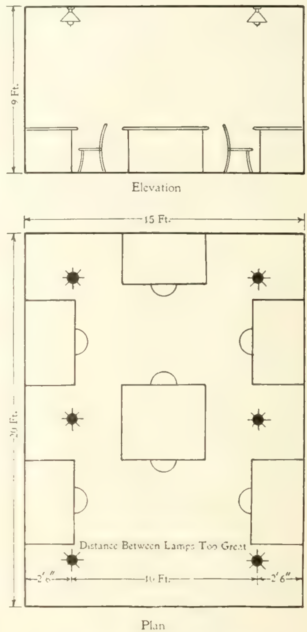

FIG. 5—TWO ROWS OF LAMPS
These lamps are the proper distance from sides of room but the distance between lamps is too great.

stated that for office work an intensity of about three foot-candles is necessary and, based on this fact, the number of watts required may be determined. The office shown in Fig. 2 may be taken as an illustration of such a case. This office is too wide for one row of lamps since the desks along the walls would not be satisfactorily

lighted. On the other hand it is almost too narrow for two rows of lamps, since a reference to Fig. 3 shows that the lamps will be only five feet apart. This, however, is the alternative.

SIZES OF LAMPS AVAILABLE

Having chosen the plan shown in Fig. 3, the size of lamps is next determined. Experience indicates that four 25-watt tungsten lamps will be somewhat too small, and four 40-watt lamps a little larger than necessary to furnish the required intensity, the theoretical size of lamps required being about 30 watts. As intermediate sizes of lamps are not available, and the use of a lamp too small for the requirements is ruled out, the 40-watt lamp is the alternative. The office thus lighted with the lamps spaced a little closer than necessary, so that desks along the walls will be taken care of, and where the lamps are a little larger than required, on account of a lack of intermediate sizes, receive the criticism of being overlighted. Hence for offices of certain sizes it is impossible to have standard spacings and, even when coming close to it, an infinite variety of sizes of lamps would be necessary to provide a standard intensity of light.

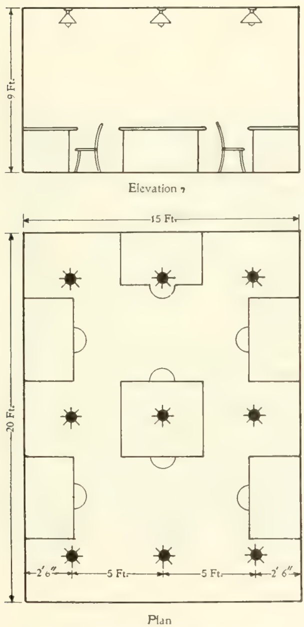

FIG. 6—THREE ROWS OF LAMPS
This is a good arrangement for a room of this size when crowded with desks.

Reference to Figs. 4, 5 and 6 will show another case where the width of the office is somewhat too small for three rows and somewhat too large for two rows. Two rows might be used as shown in Fig. 4 and the standard spacing of 7.5 feet met, but to do this the lamps would have to be so far from the walls as to yield poor re-

sults for desks along and facing the wall. If, as in Fig. 5, the two rows of lamps are so spaced that they take care of desks along the wall, then the space at the center of the office is not well lighted. The alternative is to use three rows, as shown in Fig. 6, which, while furnishing excellent light over the entire desk surface, is open to the criticism that there appear to be too many lamps in the office.

The usual policy in all cases of this kind was to lean toward over, rather than under-lighting. Both of the offices referred to in the preceding paragraphs are excellent examples of the problems presented. These offices are a little too narrow for one scheme and

FIG. 7—TYPICAL OFFICE
Showing effect of tungsten illumination.

somewhat too wide for the other. In each case the larger number was decided upon in order to provide satisfactory light without the addition of drop lamps. A typical office is shown in Fig. 7.

OTHER FACTORS

These irregularities of size are constantly encountered, and each case should be given separate attention. The larger number of lamps and the greater satisfaction attending their use should be weighed against a smaller number, and the decision based on the needs of each office. Usually, however, when it comes to making

a decision between over and under lighting, it is best to err on the safe side, particularly in the case of factory offices where voltage conditions are sometimes such as to reduce the quantity of the light, and also where losses of light due to dust and dirt on the lamps and reflectors are usually large enough to warrant an addition to the necessary light intensity to start with, so that the average may be about the desired value.

The matter of providing different intensities of the light for the purpose of taking care of varying external conditions such as color of surrounding walls and ceiling, is greatly simplified by having the lamps distributed as described in the preceding notes. In such cases larger or smaller lamps and reflectors can be substituted if a different intensity is found necessary after the installation is completed, without in any way destroying the uniformity or the acceptability of the resulting light.

These notes apply specifically to offices where the ceiling height ranges from eight to 13.5 feet. With higher ceilings the spacing of lamps may be somewhat greater and the size of lamps larger than indicated in the foregoing. The greater ceiling height permits of satisfactory distribution of the light with increased spacing, and larger lamps may be used to advantage both on account of the smaller number of outlets for a given floor space and also because the increased mounting height reduces the effect of glare which would be in evidence were large lamps mounted more nearly in the line of vision.

LIGHTING CALCULATIONS

A difficulty in predetermining exact illumination results lies in the fact that the illumination secured from lamps mounted overhead is affected both by the direction and distribution of the light from the lamps, and by the additional light due to reflection from ceiling and walls in the one case, or by the absorption of the light on very dark ceiling and walls in the other. Illumination work, therefore, can scarcely be called an exact science, but should properly be classed as a branch of work in which experience and experiment largely predominate. Theoretical and abstract considerations undoubtedly have a certain bearing on the case, but should rather be subservient to the judgment resulting from experience and also to the testimony of those who, in using various kinds of

light, have noticed certain physical or other effects, although perhaps ignorant of the scientific side of illumination.

From this viewpoint it is not difficult to realize that the calculation of illumination in practical cases must be based almost entirely on constants which have resulted from other installations of a similar nature. Evidently then the most simple method of calculation in illumination work is to measure the intensity of the light on the working surface in some satisfactory installation where certain known surrounding conditions exist, and observe the watts per square foot required to produce this effect. If as a simple illustration the watts per square foot are found to be 1.5 and the intensity on the working surface three foot-candles, a constant may be found, which in this case would be $1.5 \div 3 = 0.5$, and this constant may be used to determine the watts per square foot required to produce unit intensity in all cases of a similar nature where lamps of the same type are to be used.

The problem then in finding the total wattage necessary to provide satisfactory light in a given location is to determine by measurement the area of the floor space in square feet. This area multiplied by the watts per square foot required to furnish unit intensity, indicates the total watts required in order to provide unit intensity on the working surface. The value of the watts per foot-candle when multiplied by the total intensity expressed in foot candles necessary for the work in question, equals the total watts to be installed. Tables are now available giving these constants based on the experience of others in a variety of cases, and also the foot-candle intensity required for various kinds of work. Some tables indicate a constant called the "lumens per watt," which, put in simple language, means the number of foot-candles intensity produced per watt per square foot of floor space. This constant is the reciprocal of the one given above, and when used, the area of floor space, instead of being multiplied, should be divided by this constant.

THE INCANDESCENT LAMP IN USE

B. F. FISHER, Jr.

INCANDESCENT lamps are commonly considered from the point of view of the single unit because it is customary to see them in use singly or in small groups. A single lamp is an insignificant piece of apparatus, but more than fifty persons have handled the various parts during the process of manufacture, and these parts have gone through many distinct and different operations, a considerable number of which require a high degree of accuracy and no small amount of that faculty so rarely found in the type of female help common in lamp factories, namely, personal judgment. Reference is made to this because so many of the operations in the manufacture of an incandescent lamp are performed by girls, although it is generally understood that woman's strength lies in intuition, rather than in personal judgment.

Have you ever stopped to think how much the electrical industry as a whole is dependent on the satisfactory performance of these lamps; that the prosperity of the entire electrical industry is dependent on their performance and that the great electrical manufacturing interests could not have reached their present magnificent proportions for years to come, if they could have ever reached them, if it had not been for these little lamps which are almost overlooked in their insignificance. No matter how prosperous the electrical business is or how much this business may be depressed, there will always be a market for incandescent lamps so long as there is a generator left in operation. In a period of retrenchment or business depression operating companies can stop buying generators, transformers, meters, line material, and those greatest of conveniences, the electric heating devices, but lamps they cannot stop buying. They may by various means reduce slightly the number of lamps purchased, but so long as current is generated and sold on a large scale, incandescent lamps must be bought.

The average price of incandescent lamps is about 22 cents and this price is steadily growing higher notwithstanding the fact that the prices of incandescent lamps are steadily being reduced. This is because the use of the higher priced lamps, such as the metallized filament, the tantalum and the tungsten lamp, is steadily increasing in proportion to the total number of lamps used. The average consumption of energy by incandescent lamps can be taken as approxi-

mately 50 watts, and during the average life of a lamp, which is approximately 1 000 hours, energy to the amount of 50 kilowatt-hours will be consumed. At seven cents per kilowatt-hour, the average price for lighting current, this energy would be valued at $3.50, which is a tidy earning capacty for an insignificant 22 cent article with a short life. The value of the energy it consumes is thus fifteen times the cost of the lamp itself.

When we leave the individual lamps and consider them collectively, it is somewhat like departing from a single grain of sand to the hills along the seashore. From the most reliable reports at hand it is believed that the value of the incandescent lamps marketed during the past year was in excess of $18 000 000 and, with an average price for lamps of about 22 cents, the total number of lamps marketed was in excess of 82 000 000. It is estimated that about 70 percent of all lamps in use are renewed once a year and, if this estimate is correct, and the lamp sales last year amounted to 82 000 000 lamps, then the lamps in use last year were in the vicinity of 120 000 000, making one and one-third lamps for every man, woman and child in this country. When one looks on lamps in this way, their insignificance disappears and they take on a rather important economic and business aspect.

From the general concensus of opinion we are led to believe that the lamps installed average between one and one-half and two hours burning per day, which for the 365 days, taking the lower figure, would make 550 hours burning per year. With an average consumption of 50 watts per hour these 120 000 000 lamps would consume 3 300 000 000 kilowatt-hours which at seven cents per kilowatt-hour would make $231 000 000 as the annual income derived by central stations for the current consumed by incandescent lamps. There may be some errors in including in this grand total such lamps as are used in street railways and isolated plants, but the error in the income secured from the sale of current consumed by incandescent lamps is not great, and this income constitutes the principal source of revenue for our central stations. It is from the earning ability of these lamps that the money is derived with which to buy generators, switchboards, transformers, wattmeters, etc., and it is on the volume of demand for this class of apparatus that the prosperity of the electric manufacturing industry in general is dependent.

Consider the value of the incandescent lamps consumed on the circuits of a 1 000 kilowatt machine if operated to its full capacity

on lighting service. Renewals would be required for about 20 000 lamps per year and, at 22 cents per lamp, this would make $4 400 in net value for the lamps consumed per year. As the life of such a generator is indeterminate, an average service of twelve years has been assumed as the machine would be apt to be obsolete at the end of that time. In these twelve years the value of the incandescent lamps consumed by this machine would be in the neighborhood of $52 000, and if the value of the generator and switchboard for such a machine aggregates $25 000, the value of the incandescent lamps used is about double the value of the large station apparatus. From this it is apparent that the incandescent lamp business is not a business of first installation, but it is in the strictest sense of the word, a business of renewals.

This question of renewals brings us to the incandescent lamp in use and it is surprising how seldom we find incandescent lamps properly used. The illuminating engineer will tell us that light sources should be located so that it will be impossible for the direct rays of light to enter the eye; that the amount of light falling on the object to be illuminated should be a maximum and that glare should be eliminated. They also go into great detail as to the foot-candle values, the lumens per watt, etc.

The user of lamps, however, is liable to overlook one of the most important points, which is the direct relation between the cost of current and the efficiency at which lamps should be operated.

LAMP EFFICIENCIES

While it has been said that the foundation of the incandescent lamp business is renewals, this might lead to the inference that the incandescent lamp manufacturer desires his lamps to be burned out as rapidly as possible. With our present quality of lamps, however, it is necessary to operate them at higher efficiencies than normal in order to shorten their lives and, while it may seem strange to the incandescent lamp consumer, those who use lamps for lighting their home, factory, store or office, would be greatly benefited by operating the lamps at efficiencies much higher than is customary to-day. In going into this question of efficiencies a brief explanation should be made as to how the term is used, so that there can be no confusion as to just what is meant. The efficiency of incandescent lamps is usually expressed in terms of watts-per-candle, which means the total watts consumed by the lamp divided by the

mean horizontal candle-power, and the higher the efficiency the lower the watts-per-candle. Efficiency as used by the lamp man is thus the reciprocal of efficiency as ordinarily used. To illustrate, a lamp consuming 1.18 watts per candle is operating at a higher efficiency than one consuming two watts per candle.

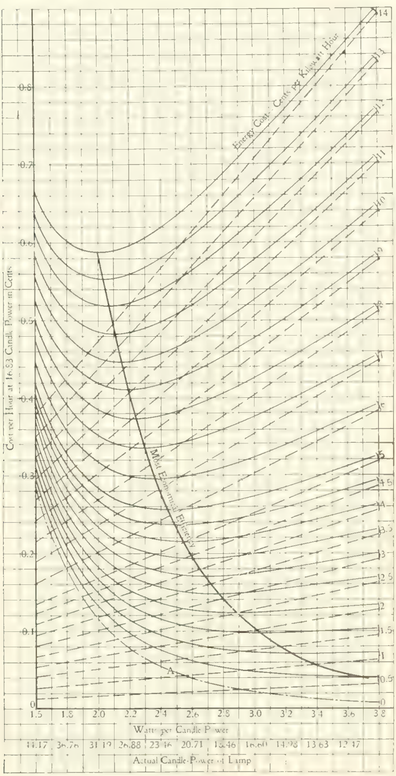

FIG. 1—CURVE SHOWING MOST ECONOMICAL EFFICIENCY OF 50-WATT CARBON FILAMENT LAMP

Normal operation 2.79 watts per candle-power; 16.83 candle-power; 700 hours life; 20c—20%=16c cost. ——— total operating costs; — — — — energy costs; — - — - cost of lamps.

Take for illustration, a 50 watt carbon lamp and note how the cost of producing light is affected by the efficiency. The relation between the cost of current and the efficiency at which lamps operate is a variable following a fixed law made up of the two elements, the cost of lamps and the cost of current consumed. The cost of current consumed to give a definite illumination value or a fixed candle-power varies directly with the watts-per-candle and hence with the price per kilowatt-hour. The cost of lamps is more complicated in that the price of the lamps varies inversely as the quantity purchased, that is, the larger the number of lamps purchased per year, the lower the

price per lamp; and the larger the candle-power capacity of the lamp, the lower the cost per candle-power. If the wholesale price for 50-watt carbon lamps is assumed at 16 cents it will be found that the cost of lamps follows the curve marked *A* in Fig. 1, which is obtained by dividing the cost of the lamp by the hours life it would have at the several watts per candle.

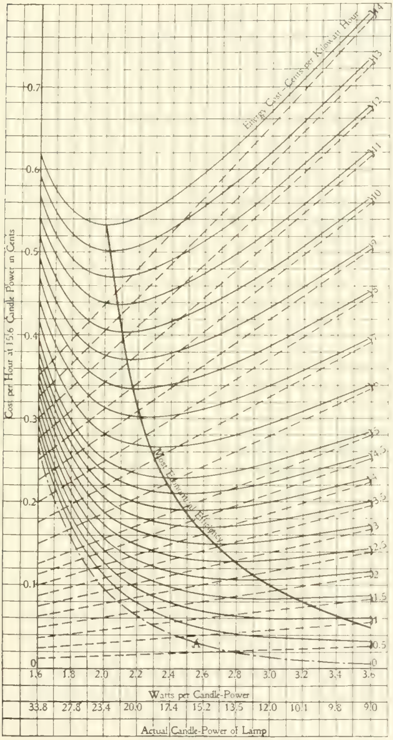

FIG. 2—CURVE SHOWING MOST ECONOMICAL EFFICIENCY OF 40 WATT METALLIZED FILAMENT

Normal operation 2.56 watts per candle; 15.6 candle-power; 600 hours life; 23c less 20%=18.4c cost. ——— total operating costs; — — — — energy costs; — - —— - cost of lamps.

The total cost of producing any given amount of light at a given price for current is the sum of the cost of lamps and the cost of current as illustrated by Fig. 1. The broken lines show the cost per hour for current at different rates when producing 16.83 candle-power at the various efficiencies or watts per candle given at the bottom of the figure. The solid curved lines show the total cost, made up of the cost of lamps and of the energy used. These curves are based on obtaining 16.83 candle-power at the various efficiencies and may be applied to one lamp, which at the different efficiencies will give different candle-power values, as shown by the lower row of figures at the

bottom of the Fig. 1 or to different lamps so selected that each will give the normal candle-power when burning at a particular efficiency, as shown by the upper row of figures. In the case of a single lamp it is assumed that the voltage is so adjusted that the desired watts per candle are obtained and the actual candle-power varies as given in the lower figures at the bottom of the figure. At 1.9 watts per candle, for example, the candle-power is about 33.7 or approximately double the 16.83 candle-power on which the curves are based. The curves of cost in this case do not give the total cost, but the cost per 16.83 candle-power, hence the actual cost of the lamp when giving 33.7 candle-power is twice that given on the curve. On the other hand a lamp may be chosen which at 1.9 watts per candle will give 16.83 candle-power. In this case the cost given on the curve applies to this lamp. The solid line passing through the lowest points of the curves of total cost is the line of most economical operation. From these curves it can be seen that for current costing as low as 0.5 cent per kw-hr. the most economical efficiency is 3.7 watts per candle, but the cost of producing 16.83 candle-power hours increases very slightly to 3.3 watts-per-candle, so that the difference in cost of operating lamps at the most economical efficiency of 3.7 watts-per-candle and at 3.39 (which is known as the "low operating efficiency") is negligible, whereas if current costs one cent per kw-hr. the most economical efficiency is 3.25 watts-per-candle (which is a higher efficiency than the low operating efficiency of carbon lamps). At two cents per kw-hr., the most economical efficiency is 2.9 watts per candle (which is above 2.97 watts per candle, the "high operating efficiency" of carbon lamps). At seven cents per kw-hr., which is the average cost for current for lighting service, the most economical efficiency is 2.3 watts-per-candle, (which is at present materially above the highest efficiency of com-

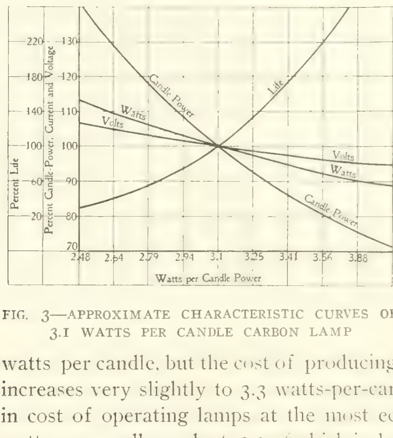

FIG. 3—APPROXIMATE CHARACTERISTIC CURVES OF 3.1 WATTS PER CANDLE CARBON LAMP

mercial carbon lamps). The short life which would be obtained at this high efficiency could be objected to on account of the frequent renewals necessary.

The cost of producing 15.6 candle-power per hour by means of the metallized filament lamp at the different costs for current per kw-hr. is shown in Fig. 2. At one cent per kw-hr., the most economical efficiency is 3.4 watts-per-candle (which is materially below the efficiency of commercial metallized filament lamps). At 2.5 cents per kw-hr., the most economical efficiency is 2.8 watts-per-candle (which is above 2.83 watts per candle, the "low operating efficiency" of the commercial metallized filament lamps). At three cents per kw-hr., the most economical efficiency is 2.65 watts per candle (which is the "medium operating efficiency" for commercial lamps), and at seven cents per kw-hr., the average cost for current, the most economical efficiency is 2.22 watts per candle (which is to-day above the highest commercial efficiency for metallized filament lamps) and might occasion a slight amount of annoyance on account of the frequent renewals.

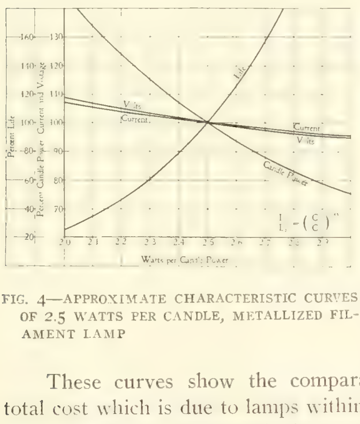

FIG. 4—APPROXIMATE CHARACTERISTIC CURVES OF 2.5 WATTS PER CANDLE, METALLIZED FILAMENT LAMP

These curves show the comparatively small amount of the total cost which is due to lamps within the range of commercial efficiencies and the relatively high amount of the total cost which is due to current. The increase in the cost on the left of the curve of *Most Economical Efficiency* is due entirely to the increased cost of lamp renewals and the increase in the cost to the right of this curve is due entirely to the increased current consumed per candle-power.

Figs. 3 and 4 illustrate the characteristic curves for carbon and metallized filament lamps showing the change in life for any change in voltage, watts, candle-power or watts-per-candle and are used in establishing the curve of cost of lamps. At the average cost of current of seven cents, the 50 watt carbon lamp is most economical at 2.3 watts per candle at which efficiency the lamp would have a

life of about 250 hours, and from the point of view of the average consumers whose current costs seven cents per kw-hr. or more, 50 watt carbon lamps which operate at 2.3 watts per candle and live but 250 hours are more economical than those which operate at 2.97 watts per candle (the "high operating efficiency" of commercial lamps), and live 700 hours. The cost of producing 16.8 candle hours at seven cents per kw-hr., and at the most economical efficiency of 2.3 watts per candle would be 0.338 cents and the cost of producing the same candle-hours at 2.97 watts-per-candle would be 0.378 cents or 18 per cent more, notwithstanding the longer life of lamps at the latter watts per candle. The same relation between the cost of current and the watts per candle is true of all lamps and, while the most economical efficiency for the different classes of lamps may vary, there is a general fixed law among all lamps which divide them in several groups.

For all costs of current above three cents the most economical efficiency for carbon lamps is materially above the high operating efficiency of commercial lamps; between three and two cents the most economical efficiencies are about the high operating efficiencies of commercial lamps and below two cents the most economical efficiencies decrease rapidly so that at one cent the low operating efficiencies are the most economical.

With the metallized filament lamp the low operating efficiency is the most economical at two cents per kw-hr., the medium operating efficiency at three cents per kw-hr. and the high operating efficiency is most economical at four cents and so on for other classes of lamps.

This study of the relation between cost of current and the watts per candle for the most economical production of light is of importance to every one interested in the electrical business, because if this relation were properly understood the cost of electric light would be reduced, the field of electric lighting would be greatly extended and the use of electricity become more popularized.

HUNTING OF SYNCHRONOUS MACHINES

B. G. LAMME

IT is not unusual for operators of synchronous machinery, such as rotary converters or synchronous motors, to write to the builders for an explanation of individual cases of hunting of their synchronous apparatus. It may be mentioned, in the request, that such hunting is either intermittent or continuous and a few minor suggestions may be made with a view to assisting the manufacturer to locate the cause. In the majority of such cases the party asking for such information is unable to furnish any material evidence as to the true symptoms which would assist in locating the source of the trouble. The phenomena of hunting are not generally understood and it could perhaps well be assumed that anyone who could put his request in such an intelligent manner as to allow a definite and satisfactory answer would probably be familiar enough with the problem to locate the difficulty himself.

In answering such questions in a general manner, several causes for hunting can be suggested and possible remedies offered which may be of assistance in analyzing and correcting the trouble.

One cause of hunting in a synchronous motor or rotary converter is found when the ohmic drop in the supply line is relatively great. This high line drop may be caused partly by other apparatus on the same circuit. If, therefore, the synchronous motor is operating normally under a condition where the ohmic drop in the line is near the critical point which will cause instability of the motor, then the addition of a little load on the same line may increase the line drop sufficiently to cause the synchronous motor to hunt. The amount of line drop permissible before hunting occurs is, to a certain extent, a function of the design of the synchronous machine itself. If the field of the motor has ample dampers of a well-distributed type, the permissible line drop without hunting will be greater than when there are insufficient dampers or no dampers at all. Also, the relative proportions of the armature and field windings of the synchronous motor and the magnetic arrangement of the parts may have some influence. It is, therefore, impossible to give any definite statement in regard to this cause

and its cure, except to say that if the ohmic drop in the line is relatively high, say 15 percent or more, then the best course would be to reduce it very materially. If the synchronous motor field has no dampers, then possibly much less than 15 percent ohmic drop in the line will cause trouble and should be remedied in the same way. This remedy could consist in lowering the resistance of the transmission line, or in using a higher voltage on the line by means of suitable transformers.

A second cause of hunting in synchronous motors or rotary converters may be found in irregular action of the prime movers in the generating system. If the generating machinery tends to hunt, even slightly, then a synchronous motor on a circuit from such generators may tend to hunt to a much greater extent, especially if there is considerable ohmic drop in the line and there is but little damping capacity in the field of the motor. Such hunting at the generating plant may occur with two or more machines which do not operate well in parallel, or when there is a critical load on one or more machines which causes instability in the prime mover governing apparatus. In fact, there may be a number of causes for slight hunting at the generating plant and this may be periodic, depending upon various conditions. Belt-driven, waterwheel driven or steam-turbine driven generators are less liable to cause hunting of a synchronous motor, than engine type generators. If the prime movers of the engine type generators are direct-coupled gas machines, the conditions are even worse than with steam engines.

A third condition which may cause hunting in a synchronous motor may be found in other synchronous apparatus on the same system which is unstable and tends to hunt. One synchronous motor or rotary converter which tends to hunt, even slightly, may cause other synchronous apparatus to hunt even to a greater degree, especially if there is considerable ohmic drop in the system. In other words, one hunting machine in the system may cause disturbances in all other synchronous machinery in the same system. The disturbing machine may be one which is overloaded at times, or which has insufficient dampers, or which has too great an ohmic drop in its own supply lines. Even if the large drop is only in its own individual line, the hunting, if once established, may cause oscillations clear back to the generating system, which, in turn, may set all the synchronous apparatus to hunting.

The remedy for the above condition is to have the synchronous machinery well damped and to have a limited ohmic drop in each circuit. An additional remedy is the use of induction motors, especially those with cage type secondaries, located in the immediate neighborhood of the hunting machine and on the same supply system. A secondary of an induction motor acts, to a certain extent, as a damper on fluctuations in the frequency of the supply system. A comparatively small induction motor may quiet the hunting of a large synchronous motor. One instance was noted where a 100 horse-power induction motor operating in the immediate neighborhood of two 250 kw synchronous machines exerted such a damping action that the synchronous machines would not hunt when the motor was connected to the circuit, but would hunt badly when the induction motor was not running. Induction motors of comparatively small slip, with cage-wound secondaries, seem to exert the best damping action. A number of small motors could, of course, exert the same correcting influence as one larger one.

A fourth cause of hunting on a synchronous motor may be found in the nature of the load on the motor. If the motor is carrying a load which can pulsate with any uniformity, then such pulsations may start the synchronous motor itself to hunting. This condition, however, is rather unusual.

NOTES ON FACTORY POWER COSTS

H. H. HOLDING

THE growth of the modern factory has necessitated the introduction of various methods of transmitting power from the prime mover to the individual machines. The power system as applied to a manufacturing plant may easily be separated into two divisions, namely, the source of power, and its transmission.

TRANSMISSION

Several methods of transmitting power from the prime mover to the machinery have been devised. The system most commonly used, however, consists of various arrangements of shafting and belting, and it is this system which will be considered in comparison with electric drive. In this connection it is well to remember that an electric drive as applied to the factory is purely a transmission system, a medium for transmitting power from its source to the tool to be driven. It can deliver no more power than it receives, but is, on the contrary, subject to losses.

If a factory is operated through a shafting transmission, certain main shafts, at least, must run whether the factory is operating at full or partial capacity, and the average shaft driven plant has an entire system of shafts and belts which must be run to operate even one department. This condition makes the factory one huge machine whose only efficient point of operation is full load. The friction load of such a factory varies with the nature of the industry and the care given the transmission, but it is rarely less than 20 percent of full load and is frequently 60 to 75 percent.

The windage of high speed pulleys and belts is an important factor which is often neglected; also, the friction of bearings is greater under load than when running idle and is difficult to measure by the means usually at hand. So the actual friction load of a mechanically driven plant is more or less of an uncertain quantity. In comparing shaft and belt drive with electric, it may safely be assumed that the unknown increment of loss under load will more than balance the small loss in electric drive, which will be due to methods of transmitting power from motor to tool. The percentage losses in an electric drive, if it is properly designed, are largely independent of load, as the motor itself is more efficient at full load, and

the wiring system is more efficient at light load. The electric system should be designed as nearly as possible, to have the same efficiency throughout the varying conditions of factory output, a condition which is not possible with any mechanical system of transmission.

Consider for purpose of comparison, a factory requiring 100 horse-power of useful work. By useful work is meant energy delivered to the tools in the factory, including the inherent friction of the tools themselves. An electric transmission can be devised with an efficiency of 80 percent, including motor and line losses, so a belt transmission of equal efficiency at full load will be assumed for comparison. In other words, in order to deliver 100 useful horsepower the shafting and belt loss will be 25 horse-power.

The two systems may be compared by referring to the diagram in Fig. 1. Here are shown two figures having equal bases and altitudes. The unshaded portions are equal and represent equal useful work from zero at the apex to 100 horse-power at the base. The shaded parallelogram in *A* represents a shafting load of 25 horse-power, and has the same width from top to bottom, while the shaded triangle in *B* represents losses in the electric transmission and varies in width from zero at no load to 25 horse-power at full load. A horizontal line drawn through these figures at any point will be divided into two parts; a light and a shaded part. The ratio of the length of the light part of the line to its entire length will be the efficiency of the factory at the point of factory load. Thus a line XY and $X'Y'$ drawn one-fourth from the top, shows the efficiency at one-fourth full load. If XY is eight inches long, ZY is four inches long; hence ZY equals one-half or 50 percent. If $X'Y'$ is five inches long $Z'Y'$ is four inches long; hence $Z'Y'$ equals 80 percent. At one-half load, the relative efficiencies are 66 2/3 and 80 percent. At three-fourth load, 75 percent and 80 percent. At full load the efficiencies are equal, as assumed, both being 80 percent.

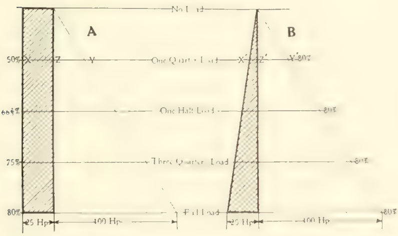

FIG. I—COMPARISON OF SHAFT DRIVE AND ELECTRIC DRIVE

A—Shaft drive. *B*—Electric drive. The shaded portion represents losses.

The average factory operates at about 25 percent of its capacity throughout the year, so the relative efficiencies of the two drives are about 50 percent shaft drive and 80 percent electric drive; this is assuming the same full-load efficiency. If the usual condition of high friction loss in the shaft driven factory prevails, the comparison in favor of electric drive is much more marked. In the comparison just made it is assumed that the electric drive is designed so that the useful work bears a constant relation to the total input of the system.

The theoretically ideal system is, therefore, one having the tools driven by individual motors. This arrangement is not always practicable, however, as for example, when the tools are small with a small power requirement, or when the operating current is purchased at a rate involving the total connected horse-power in the system. The first exception is because of the low efficiency of very small motors, say below one-half horse-power, and the second because the total horse-power connected will be high, with a correspondingly high rate for the current. A combination of group and individual drive can usually be devised which will approximate the ideal and in some cases group drive will accomplish an equally good arrangement.

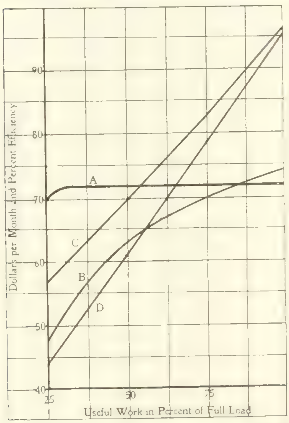

FIG. 2—EFFICIENCY AND COST CURVES

A and *B*, efficiency curves; *C* and *D*, cost curves, demand rate; *A* and *D*, for 3-5 hp motors; *B* and *C*, for 1-15 hp motor.

The use of too large motors is a common fault. With the direct-current motor the tendency is toward over motoring. The induction motor, being free from moving contacts, lends itself more readily to sudden overloads without destructive effects, and therein lies the secret of the success of polyphase motor drive in the factory. A well designed polyphase motor has a high efficiency from one-half load to one and one-half load and can carry larger loads for a brief time. It can, therefore, be applied of such size as to operate normally near full-load and still be able to carry abnormal loads when the demand is made upon it without the loss of either efficiency or durability.

The effect of proper grouping upon the efficiency of a factory drive is shown in Fig. 2. Assume a shaft of 100 feet length with 12 bearings and about 20 tight and loose pulleys, for operating a group of tools which can be run successfully by a 15 horse-power motor. The efficiency of the system is shown in curve *B*, it being assumed that the belts are shifted to loose pulleys as the tools are shut down. The efficiency falls rapidly as the load goes off because of the fixed loss in the shafting and the drop in efficiency of the motor under light load.

If the same shaft is divided into three lengths and each section driven by a five horse-power motor, and the group shut down by stopping the motors as the tools go out of service, the efficiency of the system will be as shown by a curve such as *A*. A high efficiency is maintained beyond one-fourth load. Curves *C* and *D* represent the cost per month for various percentages of useful work at the demand rate of a large eastern electric company, showing also the advantages of the use of three smaller motors over the one larger one at light load with central station service. This is due in part to the greater efficiency of the transmission system as shown by *A* and *B*, and in part to the fact that the rate for current assumes a lower demand for the three motors than for the one 15 horse-power motor.

The foregoing illustration is used merely to show the fundamental principle involved in motor application to factory operation. The application of this principle necessitates a study of the requirements of special cases. There are in nearly every industry some characteristic in which motor drive will show a decided advantage other than in transmission. Some of these may be briefly mentioned:—

Homogeneity of product due to evenness of speed.

Increased product due to maintenance of speed.

Cleanliness due to fewer dirt-carrying belts.

Better light and decreased fire risk due to absence of vertical belts from floor to floor with attendant belt chutes or floor openings.

Increased facilities for handling material during process of manufacture, because of ability to arrange machinery to advantage in a given floor space.

Decreased liability to injury of operators, because of ease of stopping departments independently. Lessened strain on buildings

because of absence of very large shafts and consequent vibrations

Better sanitation because of ability to isolate departments with attendant dust or noxious fumes.

Distant control of apparatus possible.

Automatic operation easy to attain.

A comprehensive list of motor applications for various operations in the industries, would be too long to enumerate here, but the power engineer will gradually accumulate a mass of data which will help him greatly in making up an intelligent engineering report. The advice of specialists should be sought in particular applications. The builders of shop tools are gradually adapting their product to motor drive, in many cases a special motor being required for a peculiar adaptation. The more prominent motor manufacturers, however, have a standard line of motors with varying characteristics, and it is nearly always possible to select a standard motor for use in the factory, which is well adapted to the requirements.

THE SOURCE OF POWER

In determining the source of electrical energy for the operation of an electrically driven factory, there are two methods of supply to be considered, viz., a privately operated plant and power purchased from a central station.

The private plant has two elements making up the cost per kilowatt-hour.

1—Those costs which may be classified under investment.

2—Those costs which are due to operating expense.

The first set of costs are too often entirely neglected or are given too little analysis with respect to the operating conditions in the factory.

In considering the efficiency of the transmission system it is found that the ratio of useful work to total work determines largely the saving to be made by substituting electric operation for shaft drive. The average operating conditions as to power required for useful work is also an important factor in determining the cost per kilowatt-hour of the electrical energy supplied for operation. The source of supply must be sufficient to furnish energy for the maximum requirement. Hence the private plant which we shall now consider must be large enough to supply the transmission system during the time of maximum output. The relation of maximum and average power requirement varies in dif-

ferent industries and a knowledge of this relation is necessary in computing the cost of energy per unit output of factory.

The ratio of average requirement to the maximum is usually expressed in percentage and is called "load factor". The load factor varies from nearly 100 percent in electrolytic work to five percent or less in woodworking shops.

The operation of a private plant at 100 percent load factor has the disadvantage of no reserve and is, therefore, undesirable because of the danger of breakdown and consequent loss in factory output. On the other hand, the carrying of a duplicate plant throughout has the disadvantage of consequent low load factor and is objectionable, as will be shown.

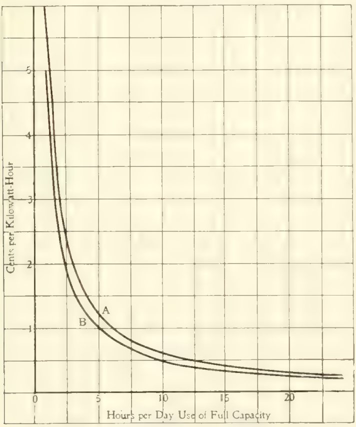

FIG. 3—INVESTMENT COST CURVES

Based on investment of $125 per kw capacity, $18 per year fixed charge.
A—300 days operation per year.
B—365 days operation per year.

Consider first the cost due to investment. The first cost of the plant is made up of:—Ground space for power house; buildings; generators and prime movers; boilers, gas producers or fuel using devices; auxiliaries, such as pumps, condensers, etc.; piping, switchboards, cables, etc. The yearly charges against the investment are made up of depreciation, interest, taxes, insurance, rental value of ground and building space, etc.

If an investment of $125 per kw capacity be assumed, a yearly charge of $18 is fair. This will be made up, for example, of:—Depreciation, 8 percent; interest (average) 3 percent; taxes, insurance, etc., 3.4 percent; total, 14.4 percent.

In a year of 365 days there are 8 760 hours. If the $18 yearly charge is spread over the entire year a charge of 0.205 cent per hour will obtain. Hence, if the entire plant is operated at full capacity throughout the entire 8 760 hours per year, the cost due to investment is 0.205 cents per kilowatt-hour. As the hours of full-load operation decrease the charge per kilowatt-hour increases as

shown in Table I and Fig. 3. From this figure it may be seen that if the plant operates at full-load for ten hours per day, the investment charge is 0.49 cent per kilowatt-hour. If 300 days are taken as the average working year, the charge for ten hours is 0.6 cent. By taking 0.6c as the investment cost per kilowatt-hour on a plant operating 10 hours per day during a 300 hour year, Table II may be derived showing the charge to apply under various load

TABLE I—INVESTMENT COST PER KILOWATT-HOUR

Based on full load operation for 365 days of 24 hours each. Fixed charge—$18.00 per year per kilowatt installed.

Hours Use Per Day	1	5	8	9	10	12	18	20	24
Cents per Kilowatt-Hour	4.92	0.98	0.61	0.54	0.49	0.41	0.27	0.24	0.205

factors. Fig. 4 shows in plotted form the variation of the charge at 10 hour operation. In Fig. 5 the lower group of curves show the variation with several different plant costs, from $50 per kilowatt to $150 per kilowatt. The upper group of curves shows the total kilowatt-hour cost for several different plant costs and operating costs. It is seen that at 25 percent load factor, which is a very common operating condition, a plant could be used costing only $50 per kilowatt with an operating cost of three cents per kilowatt-hour, and obtain a kilowatt-hour cost practically the same as though

TABLE II—INVESTMENT COST PER KILOWATT-HOUR

Based on full load operation for 300 days per year, 10 hours per day. Fixed charge $18.00 per year per kilowatt installed.

Percent Load Factor	10	20	25	30	35	40	45	50	55	60	75
Cents per Kilowatt-Hour	6	3	2.4	2	1.7	1.5	1.33	1.2	1.09	1	0.8

there were used either a $125 plant with operating cost at 1.5 cents or a $150 plant with one cent operating cost. With less than 25 percent load factor the cheaper plant shows a cheaper kilowatt cost, but with a load factor greater than 25 percent the more expensive plant shows an advantage.

Using the investment curves in Fig. 5, by the process of proportion, the overhead cost can be obtained for any cost of plant for

any load factor assumed for a factory, or for any assumed yearly investment.

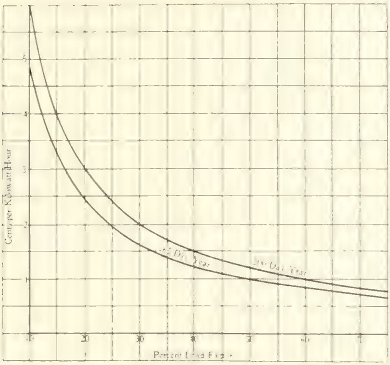

FIG. 4—INVESTMENT COST CURVES

$18 per year fixed charge. 10 hour day for 365 and 300 day year.

For example, the curve of the $100 plant cost at 30 percent load factor shows 1.6 cents overhead cost per kilowatt-hour, with

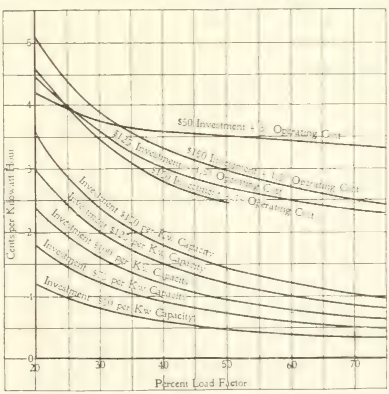

FIG. 5—INVESTMENT AND TOTAL COST CURVES

300 days per year, 10 hours per day, 14 percent per year fixed charge.

$18 yearly investment charge. Required to find, at the same load factor, the charge for a $15 yearly fixed cost. The proportion then

is, — $\frac{1.6}{X} = \frac{18}{15}$; or $\frac{15 \times 1.6}{18}$ = 1.34 cents per kilowatt-hour at $15 fixed charge.

Example: If 1.34 cent is the overhead cost at 10 hour operation, what will be the cost at 23 hour operation? $\frac{1.34 \times 10}{23} = 0.58$ cent

TABLE III—LABOR COST WITH VARYING LOAD FACTORS

Load Factor, Percent	10	20	30	40	50	60
Labor Cost per kw-hr.—cents	3	1.5	1	0.75	0.6	0.5

Operating Expenses:—The second set of costs, classified as "Operating Expenses", is not so easy to determine, as it is made up of a number of variables. The principle items, however, are labor, fuel, oil, waste, water and incidentals. All of these vary with the size and cost of the plant and with the load factor. For the sake of comparison we can assume some values, for example, assume a 100 kw plant, which is a common size for a factory. It can be run by an engineer who does his own firing. If he is paid $75 per month the cost per hour is 30 cents. With varying load factors the cost per kilowatt-hour for this item will be as given in Table III.

TABLE IV—TOTAL EXPENSES—CENTS PER KILOWATT-HOUR

$50 per kilowatt plant at 12 pounds coal per kilowatt-hour.						
Percent Load Factor	20	30	40	50	75	100
Labor	1.5	1.0	0.75	0.6	0.45	0.3
Coal	2.0	2.0	2.00	2.0	2.0	2.0
Incidentals	0.35	0.35	0.35	0.35	0.35	0.35
Investment	1.2	0.8	0.6	0.48	0.36	0.24
Total Cents per Kw-Hr.	5.05	4.15	3.70	3.43	3.16	2.89
$150 per kilowatt plant at 7 pounds coal per kilowatt-hour						
Labor	1.5	1.0	0.75	.5	.45	.30
Coal	1.17	1.17	1.17	1.17	1.17	1.17
Incidentals	0.25	0.25	0.25	0.25	0.25	0.25
Investment	3.6	2.4	1.8	1.44	1.08	0.72
Total Cents per Kw-Hr.	6.52	4.82	3.97	3.46	2.95	2.44

The fuel costs per kilowatt-hour will vary somewhat with the load-factor but not sufficiently to consider in this rough comparison. This cost will vary greatly, however, with the cost of the plant and

with its care and attention. The oil, waste and water will vary with the cost of the plant and its attention.

Let us compare two plants of 100 kilowatts capacity of extreme values, say $50 per kilowatt and $150 per kilowatt. We will assume that the $50 plant requires 12 pounds of coal per kilowatt-hour and the $150 plant uses seven pounds. Assume that the coal costs $3.50 per short ton delivered. With these assumptions Table IV gives the values at various load factors, the investment charge being taken for ten hour operation, 300 days per year.

The values given in Table IV are plotted in Fig. 6. It is shown that, with the assumed values of coal consumption, etc., the expensive plant is cheaper at load factors greater than 50 percent, while for lower load factors the greater investment charge of the more

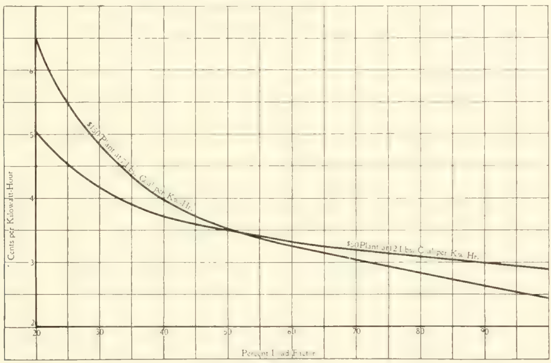

FIG. 6—TOTAL COST CURVES, 100 KW PLANT

$150 per kw plant burning 7 lbs. coal per kw-hr., and $50 per kw plant burning 12 lbs. coal per kw-hr., coal costing $3.50 per short ton.

costly plant outweighs its efficiency. These curves show very clearly the effect of the investment charge upon the kilowatt cost of current produced by a private plant. It is quite evident that the average kilowatt-hour output of the plant is the determining factor of the cost, and not the efficiency of the plant itself, because a plant of high efficiency is expensive in first cost and the overhead cost thus involved overbalances the saving in operating cost unless the load factor is high.

The problem of load factor is one which the central station manager has faced for years. That the factory manager has just

begun to realize its presence is evidenced by the increasing number of power customers of the central station at rates which have heretofore been considered excessive by the factory managements. The integrating wattmeter shows a surprisingly low energy consumption for the average factory, as compared to the maximum demand; thus the average low load factor of factories has become apparent.

CONCLUSION

The load factor is the important condition which determines the advantage to be gained in both transmission of power in the factory and in the source of current for an electric drive. The lower the load factor the greater the advantage of electric drive over other methods of transmission. The higher the load factor the cheaper the rate per unit of energy whether the current be produced by a private plant or purchased on a demand basis. As the factory manager becomes better advised as to his operating conditions with respect to load factor it is easier for the central station to show him the advantages of purchased current. Lack of knowledge on the part of the manufacturer as to the actual power required in a given time is the greatest barrier to the power man's argument for purchased current.

The application engineer should make himself a specialist in power transmission, and in addition should become sufficiently familiar with the peculiarity of the industries in his immediate territory to advise his clients as to best methods of motor application. He should profit not only by his own experience, but also by that of others in the same line of work. A pointer thus obtained will often prevent misapplication and misapplication is responsible for most of the dissatisfied users of electric power. The power salesman has not well performed his task if he merely signs his prospect and leaves him to use his purchased current in a wasteful manner. The signing of the customer, however, will not often be accomplished without giving him an intelligent idea of what electric drive from purchased current can be expected to accomplish for him. Comparisons of load factors of various industries will be of slight avail unless a comparison of motor application goes with it, as the consumption of current can often be varied greatly by changing the groupings of the tools. For example, the load factor of a brass-working shop was changed recently from 50 percent to 28 percent by changing the grouping of the tools, so that those usually operated at the same time were grouped together, without reducing the total shafting length or adding to the connected horse-power.

A CONVENIENT METHOD FOR DETERMINING GRADES

G. M. EATON

AN APPROXIMATE means of measuring the percent grade of railway tracks, particularly applicable in coal mining work where tools are scarce, is offered by the use of an ordinary woven tape line such as is almost always available. The method consists briefly in forming three lengths of the tape into a right triangle and using the remainder of the tape and the reel as a plumb bob, as shown in Fig. 1. A triangle with one vertical and one horizontal side is thus obtained, and the distance from the vertex of the right triangle to the rail with the triangle in position gives a

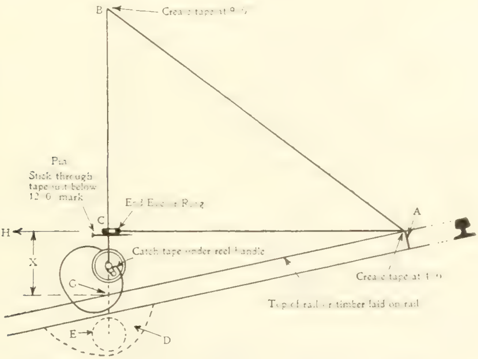

FIG. 1—DIAGRAM SHOWING METHOD OF FINDING GRADES BY USE OF TAPE LINE

direct measure of the grade in percent. The results obtainable by the method here described are fully as accurate as other data used in preparing a mine haulage proposition.

Application—The first operation consists of reeving the tape through the end eye as in Fig. 2. Stick a common pin through the tape just beyond the 12 foot mark. (See Fig. 1.) Continue pulling the tape through the end eye, until the pin comes into contact with the eye. The pin should be located so that the horizontal center line of the end eye, Fig. 1, is just on the 12 foot mark. The tape should then be creased sharply at the four foot and nine foot lines and tucked under the reeling handle below the 12 foot line. It should

then be tied to the rail at *A*, care being taken that the binding cord creases the tape accurately on the four foot line. If the character of the mine floor is such that a pocket *D* can easily be excavated, this will simplify matters, as the distance *X* can then be read directly from the tape. If it is not convenient to do this, the distance *X* can be measured with the slack tape. If two men are available for making the grade measurements, it will be found most convenient for one man to hold the tape at *B* and *C*, while the other reads or measures the distance *X*. *B* should be held by a string or wire loop which creases the tape accurately on the nine foot line. The ring at *C* should be held by its sides, between the thumb and finger, being pulled back sharply in the direction *H* to avoid sag in *AC*. *B* and *C* should be so adjusted that the ring is just clear of the pin vertically, and the tape is just clear of the end of the ring horizontally. *BC* will then be vertical since it is located by the tape reel acting as a plumb bob.

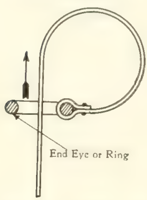

FIG. 2—METHOD OF REEVING TAPE LINE THROUGH RING

The triangle *ABC*, Fig. 1, having sides in the ratio 3:4:5, is a right triangle; therefore, *AC* is horizontal, provided *BC* is vertical and the triangle is held as indicated above. The side *AC* is 48 inches long. One percent of 48 inches equals 48/100 inches, or practically one-half inch. Therefore, every half inch of the distance *X* represents approximately one percent of grade.

Strictly speaking, the rise *X* should be measured with relation to the rail length *AG* instead of the horizontal projection *AC*. Within the limits imposed by adhesive operation, however, the discrepancy is negligible. The "half inch per percent" rule involves in itself an error of slightly less than two percent, i. e., the actual grade is slightly more than one percent per half inch. The total inherent error from these two causes is thus equal to their difference. With reasonable care it is possible to read to the nearest half of a percent of grade, which is ordinarily sufficiently accurate for commercial work.

WINDING OF DYNAMO-ELECTRIC MACHINES--XIII

CHECKING OF CONNECTION DIAGRAMS ON THREE-PHASE MACHINES

H. C. SPECHT

ONE of the fundamental considerations in connection with three-phase alternating-current circuits is that, if *at a given instant* the current in two of the lines flows in one direction, the current in the third line flows in the opposite direction. On this instantaneous basis the circuit may be treated for the purpose of analysis as though direct current were flowing. This principle may be applied to motors and generators. Accordingly a common method for checking the connections of three-phase ma-

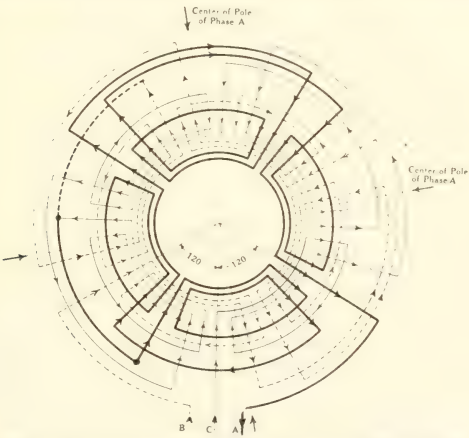

FIG. 147—FOUR-POLE, CONCENTRATIC GROUP, THREE-PHASE, STAR-CONNECTED WINDING

chines, either on the actual winding or on the diagram of connections, is to consider the current as flowing into the winding by way of one lead and out by the other two, or vice versa. Assume then in Fig. 147, a three-phase star-connected concentric four-pole group winding, that the current is entering at *B* and *C*, circulating through the windings of these two phases, and then passing from the neutral or star point through the other phase to the terminal *A*.

When applying such a method, it is quite essential that the

arrangement of the winding under consideration be known and, moreover, that a number of points be kept in mind in regard to the location of the leads, direction of polarity of the consecutive groups, and the order in which changes of polarity occur. Thus, in Figs. 148 *a, b* and *c* three methods of connection of a simple winding for a given voltage are shown, respectively, for a regular four-pole full pitch winding, a four-pole full pitch winding of the consequent pole type, and a two-pole winding of reduced pitch type obtained

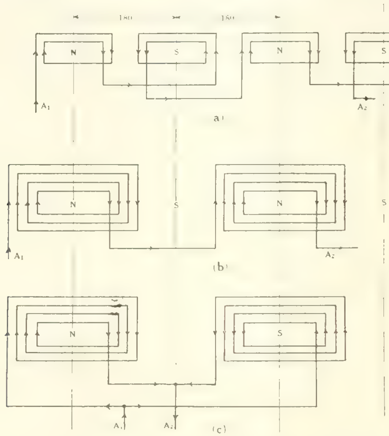

FIG. 148 (a), (b) AND (c)—CHARACTERISTIC METHODS OF CONNECTION AND ARRANGEMENT OF GROUPS

a—Four-pole winding with alternately positive and negative groups.

b—Four-pole winding of the consequent pole type.

c—Two-pole winding obtained from *b* by re-connecting the groups alternately positive and negative.

from the consequent pole winding by reversing the connections of alternate groups. The latter two combinations are sometimes used as a means of obtaining a two-speed motor with 2 to 1 speed ratio. From Fig. 148, in which a few of the possible arrangements are shown, it will be seen that it may be necessary to know in advance the type of winding in hand in order to check readily and intelligently the connections of the machine. Generally the leads of the three phases are separated by a spacing of two poles (i. e., an electrical angle of 120 degrees apart) as shown in Fig. 140.* However,

in Fig. 141,* the leads do not appear to be 120 degrees apart, on account of the consequent pole arrangement.

In many cases, particularly on rotors, it is more convenient to tap off the leads at points farther apart than two groups; in such cases the method of checking referred to above, in which the current is assumed as entering the winding at one lead and leaving it by way of the other two (or vice versa), may easily result in erroneous conclusions regarding the correctness of the connections.

This may be illustrated by reference to Fig. 149, which shows a six-pole diagram with phase *B* reversed. Assuming that the current

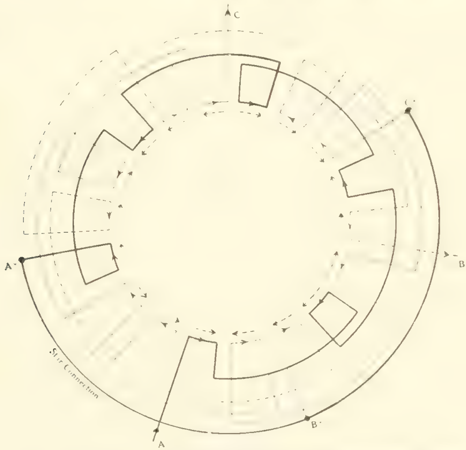

FIG. 149—SIX-POLE, THREE-PHASE, STAR-CONNECTED GROUP WINDING WITH ONE PHASE PURPOSELY REVERSED

flows into lead *A* and leaves by way of *B* and *C*, six poles per phase are actually obtained (the broken line arrows within the diagram are to be disregarded temporarily) yet with no proof that the three phases are connected in the right relation; for a further condition has to be fulfilled, viz., that the leads shall be 120 electrical degrees apart, or some multiple thereof. This latter condition is not fulfilled in the case of phase *B*, this phase being reversed. In the case of a delta connection the above rules cannot be applied directly in checking or laying out the connection of phases. Usually

*See Section XII of the present series, pp. 474 and 475 of the May, 1911, issue.

such a diagram is laid out as a star connection, the star then being connected into a delta, as shown in Fig. 150.

SIMPLE UNIVERSAL RULE FOR CHECKING

A method such as the foregoing for checking windings is obviously not easily remembered and not always readily applied. This is particularly true when a winding has to be checked directly on the machine, as it is rather difficult to trace all of the connections throughout the winding. A method which offers much better proof against mistakes, is simpler, and is easier to remember, was referred to in Section XII.* Briefly stated it is as follows:—Assume that currents from a course of power flow into all three leads of the star connection simultaneously, Fig. 151 *a,* and meet at the star point; or, in the case of a delta winding, that the current in the delta connection flows completely around the delta in either direction; then the polarity of the consecutive groups will alternate regularly around the winding, Fig. 151*b*. The windings may thus be assumed as carrying direct current, the arrows indicating the direction of the current. (The actual instantaneous alternating current is, of course, not as thus indicated, but can be assumed so for purpose of checking.) Thus, for a three-phase winding there would be three times as many poles as the rated number of poles of the machine. With the present method of checking, the actual location of the leads and the phase relation of the respective groups does not have to be considered; the fulfillment of the one condition of alternating polarity at regular intervals is a positive indication of correct connection of the groups of the winding.

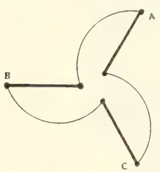

FIG. 150—METHOD OF CHANGING STAR TO DELTA CONNECTION

For example, referring again to Fig. 149, assume that the current is flowing from terminals *A, B,* and *C* to the star connection; the polarity of the groups will now be as indicated by the broken line arrows within the diagram. The fact that phase *B* is reversed is now immediately evident. The required phase relations in the winding would be obtained and the requirements of the present rule fulfilled if, for example, the terminal lead of phase *B* were connected at *B** and the present terminal *B* were made the star connection.

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*See p. 475 of the May, 1911, issue.

If the winding of a completed stator such as indicated in Fig. 147, for example, were being checked, the respective phases would be excited by low-voltage direct current applied across *ABC* connected together and the neutral point represented by $A^*B^*C^*$, as shown in Fig. 151 *a*, and the polarity of the winding explored by means of a compass or magnetized needle held within the stator near the face

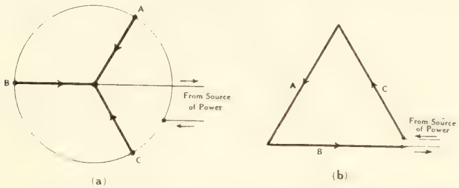

FIG. 151 (a) AND (b)—SHOWING METHOD OF CHECKING THREE-PHASE STAR OR DELTA WINDING WITH DIRECT CURRENT

of the iron. Then there should be three times as many poles as the rated number of poles of the machine, reversing alternately and spaced equally provided the machine has a balanced winding. In the case of a delta-connected winding, it would be necessary simply to open the delta at any convenient point, such as at the point of connection of one of the terminals and connect the two free ends to the source of power, as indicated in Fig. 151*b*.

EXPERIENCE ON THE ROAD

TROUBLE, BUT NOT THE FAULT OF THE MOTOR

LEONARD WORK

ELECTRICAL machinery is frequently reported as failing to perform its work properly, when the real difficulty lies entirely outside of the apparatus itself. One such case happened not long ago where a two-phase induction motor was installed to operate a vertical coal elevator, replacing an old gasoline engine.

The new motor, which was one of the latest type, looked very promising, but had hardly been started and the conveyor buckets filled with coal before it gave evidence of distress, slackened its speed, and stopped. It could not be started again, and finally the purchaser, impatient at the delay, threatened immediate rejection of the motor and the installation of another engine.

An engineer was sent for, who, on arrival, made inquiry as to the voltage and frequency of the service line, but was assured positively by the superintendent of the local power plant that the voltage and frequency were unquestionably correct and were always so maintained, but that the motor was obviously at fault in that it would not pull a load which a five horse-power gasoline engine had carried, although the motor was of twice that capacity.

An examination of the motor failed to show the slightest disorder with its windings or connections. All its circuits were clear, and, although of ample capacity, it was conceivable that in some manner the load might have become too heavy. In an endeavor to diagnose the case, it was decided to make several measurements and determine the torque necessary to start the load, the available starting torque, the frequency of the circuit and the line voltage.

It is commonly thought that measurements of this kind require an array of laboratory instruments, or other special facilities; however, all the necessary data was obtained here with a spring balance from an ice wagon, a speed-indicator and a voltmeter; and this simple paraphernalia served to locate the trouble very quickly.

The torque required to start the load was obtained by attaching the spring scales to the driving belt and pulling it slowly along, thus moving the entire load, whereupon the pointer indicated a pull of 120 pounds. The product of the motor speed times circumference of pulley gave the belt speed as 1 600 feet per minute; this multiplied by 120 pounds and divided by 33 000 gave 5.8 as the

horse-power required at full speed, which proved that the motor was far from being overloaded.

Next, the motor starting torque was measured at one foot radius. For this purpose a wooden bar was fastened across the diameter of the paper pulley and a notch was made in the bar exactly one foot from the center of the shaft, so that the hook of the scales would remain at the stated distance. The scales were then so suspended that the projecting bar would maintain a horizontal position while resting on the hook. When current was applied to the motor, the pointer registered a pull of 41 pounds, which was at about one-half the normal rated starting torque for the motor.

The cause of such a low torque could be either high frequency or low voltage or both, and steps were taken at once to ascertain these values. The first step in determining the frequency of a circuit by means of a motor is to know its no-load speed, when the full-load speed is given. The rated speed as given on the motor name plate was 850 revolutions at full-load and 7 200 alternations per minute. The synchronous speed is found by dividing the rated alternations per minute by the number of poles; the next highest number above full-load speed obtainable by dividing the alternations by an even number will be the synchronous speed, while the divisor will be the number of poles. In the present case, 900 is the next highest number above 850 obtainable with 7 200, and with eight for a divisor; hence the motor was obviously an eight-pole machine, with a no-load speed of about 900 r.p.m. on normal frequency.

With belt off, the motor was given full line voltage. The speed indicator showed 1 000 revolutions per minute, which being above synchronous speed, proved that the frequency of the circuit was high in the proportion of 1 000 to 900, or 11.1 percent, and, since the starting torque of an induction motor, within certain limits, varies almost inversely as the frequency, this was evidently one cause contributing to the weakness of the motor. There remained only the question of line potential. A voltmeter applied to the motor terminals, with the auto-starter in running position, showed the voltage to be 154, whereas the motor was rated at 200 volts.

The whole cause of the trouble was now apparent, and, accordingly, measures were at once taken to correct the abnormal conditions. As soon as the frequency was lowered to the correct value and the voltage raised to normal, the motor started up and pulled its load in such a business-like way and with such evidence of reserve power that it thoroughly redeemed itself.

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550—Single-Phase Railway Calculations and Methods of Power Distribution — *a* — What is the method of predetermining the line k.v.a., line loss, line kw and average kw at the power house for a single-phase railway after the speed-time curves, current-time curves, and kw input curves have been plotted? *b*—How is the size of track rail bonds determined? *c*—The proposed line is a double track system with three-phase hydraulic generation stepping up by means of transformers connected in three-phase T to 110 000 volts, using three-phase V for purpose of distribution, the ground being employed as the third line of the high-tension distribution circuit. The step-down transformers are correspondingly to be connected in V connection to ground on the high-tension side, one secondary terminal being connected to the rails and the other to the trolley to supply single-phase current. E. F. R.

a—The k.v.a. at the motors equals $\frac{N \times C \times E}{1000}$, where N equals number of motors, C = amperes per motor, and E = voltage at motors, the corresponding true power in kw being the product of this value and the power-factor of the motors. The trolley k.v.a. and kw are obtained from these by adding from three to five percent to allow for losses in the car transformer preventive coils and wiring. The voltage necessary to pass any given starting current through the motors may be found by using the following data, obtainable from the motor performance curve:—the voltage on which the motor is to run, the power-factor and electrical efficiency corresponding to this voltage and current. In triangle ABC, Fig 550 (a), let AB and cosine ϕ represent these two quantities. Then $AC = AB \times$ cosine ϕ, represents the working voltage on the motor. $BC = \sqrt{AB^2 - AC^2}$, represents the inductive drop in the motor. The working voltage may be divided into two quantities, viz.—AD, which represents the voltage necessary to balance the back e.m.f. due to the motor speed, and DC, which represents that necessary to overcome the motor losses. The first of these two values is the

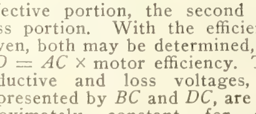


FIG. 550 (a)

effective portion, the second the loss portion. With the efficiency given, both may be determined, i.e. $AD = AC \times$ motor efficiency. The inductive and loss voltages, as represented by BC and DC, are approximately constant for any given current but the back e.m.f. varies directly with the speed, being zero at the instant of starting and being represented by AD when full voltage is first applied to the motor terminals. Therefore the impressed voltage necessary to start will be represented by $BD = \sqrt{BC^2 + DC^2}$. Using this value in the first equation given, the k.v.a. or kw at start may be determined. To determine the loss in the trolley and track circuit for any given run, the procedure would be as follows:—knowing the k.v.a. at the trolley with the corresponding trolley voltage and also the resistance of the circuit, it is then merely a problem of plotting the different

C^2R loss values on a time base and integrating the area between this curve and the base line. It will be found convenient to plot these values directly on the speed-time curve. If a distance curve is first plotted on the same sheet the various C^2R values will be more easily determined. The shape of this curve will necessarily depend on the position of the power house. For a given run the various values of trolley kw input may be plotted on a time base, the area between this curve and the base line representing the total car kw-hrs input for that run. The average kw at the power house is, of course, the average of the sum of the total line loss and the total car input. The integrations of these areas are most easily obtained by means of a planimeter. *b*—Theoretically, rail bonds should be of such size and so applied that the voltage drop through a section of the rail including the joint is the same as that through a section of similar length, not including the joint; a rule which may be applied to single-phase railways equally as well as to direct-current work. Bonds larger than the equivalent of No. 0000 B & S copper wire have not been required in any case of which we know, up to the present time. *c*—This method of distribution is not practicable for two fundamental reasons. First, it is not possible to obtain single-phase power from a three-phase circuit by means of static transformers without prohibitive unbalancing. This is covered by Nos. 299, 363, 504, and 515, and article referred to therein, by Mr. Chas. F. Scott, in the JOURNAL for January, 1906, p. 43. Second, a ground return for one side of a high-tension transmission line is not considered good practice. A proper arrangement would be to separate the two phases of the step-down transformers, and supply the power to separate circuits in each direction. This would serve to keep the trolley wires on each of the parallel tracks at the same potential, thereby simplifying line construction at crossovers. W. G. H. & T. V.

551—Electric Welding—I have lately encountered a problem in electric welding, an answer to which I hope you will be able to give through your Question Box. I have read Mr. C. B. Auel's article on "Electric Welding" in the January, 1908, issue of the JOURNAL, but the process described therein utilizes a carbon electrode whereas the process on which I desire information utilizes a rod of soft iron as an electrode. I would like information as to the size of iron rod usually employed, the voltage across the arc, the current density per square inch of rod, the best length of arc, and also what flux, if any, is required in the welding process. It is desired to make repairs to corroded portions of boilers by building up new metal on the corroded part of the sheets. This process has been approved by the U. S. Government, but is comparatively new on this coast, so any information you may be able to give will be greatly appreciated. R. H. F.

The process referred to is that of Flavianoff, which is a modification of the Benardos process, an electrode of the same or similar material as the article to be welded, however, being substituted for the carbon electrode. This metal electrode (which for welding iron or steel is a soft iron wire) should not exceed 3/16 in. diameter; and, although for best results they should be covered with a flux before using, still very fair success can be obtained with borax alone. Several patented fluxes are recommended by various investigators. Direct-current should be used; about 120 to 130 amperes at, say, approximately 25 volts across the arc and 50 to 60 volts at the generator. The length of the arc will be about 1/16 in. to 3/32 in. In making a weld, some little skill is required, as the electrode has a tendency to stick to the article being welded at the moment of striking the arc. By a quick yet very slight movement of the wrist, the electrode can be touched to

the metal and withdrawn to the proper distance (1/16 to 3/32 in.) without breaking the arc, and the electrode then fed steadily into the weld. The advantage of the Flavianoff over the Benardos process is that softer welds may be obtained; the disadvantage is that the work must be done much more slowly. The process has been described in various magazines, one of these articles which appears in "Engineering" under date of March 4th, 1910, being an abstract of a paper on "Steamship Repairs by Electric and Autogeneous Welding" by Mr. A. Scott Younger, read before the "Institution of Engineers and Shipbuilders" at Glasgow, Scotland. C. B. A.

552—Testing Insulation with Current Transformer—Is it possible to use a series transformer to test armatures, field coils, etc., for insulation. The windings of the transformer are for 110 volts primary to 2 200 volts secondary. It is proposed to use a voltmeter on the 110 volt side and gradually apply voltage until 1 000 to 2 000 volts are obtained on the secondary, depending upon whether the coils are old or newly wound; test to be instantaneous. The field coils and armatures in question are used on railway motors. In case of breakdown between coil and core, would sufficient power be dissipated to cause serious damage? If this method is unsatisfactory, please advise what would be the best arrangement to use and give details of construction. F. H. W.

If a current transformer is meant is should not be used for this purpose, as its output would be too small. A voltage transformer of size suitable for meter werk, while capable of developing the desired voltage, is not likely to be capable of supplying sufficient current for the purpose intended without risk of injury to its windings, and there will be too great a voltage drop due to the resistance offered to the charging current by the windings themselves. We would not recommend for this purpose anything less than a one kw, 2 200 to 110 volt, distributing transformer such as is regularly used for lighting service. With regard to breakdown between coil and core of apparatus under test no damage is likely to occur if proper circuit breakers or fuses are used in the primary (110 volt) circuit. Note No. 119 and article on "Insulation Testing" in the JOURNAL for Sept., and Oct., 1905, pp. 538 and 615. J. E. M.

553—Connecting of Two Three-Phase Transformers in Parallel—In connecting two three-phase transformers of the same capacity, designed to operate in parallel, what is the method of determining which leads from the secondary side of each transformer are to be connected to the same bus-bars of a three-phase system? R. E. S.

Two three-phase transformers may or may not be operated in parallel, according to their internal connections. The proper connection, if there is one, may be determined as follows: Connect the primary sides in parallel in any convenient way, preferably connecting each line to the two leads similarly placed on the two transformers. The secondary sides can now be tested for paralleling. Suppose, for example, that the secondary leads are numbered *1*, *2* and *3*, starting from the left, when facing the secondary side of the transformer; connect a secondary lead of one transformer to a secondary lead of the other; for example, connect leads *1* and *1* together. Then measure the voltage from each of the two remaining leads of one transformer to each of the two remaining leads of the other. If two pairs of leads are found which show no difference in voltage between individual leads of each pair, the connections are correct and the transformers may be operated in parallel when thus connected. If proper connections

can not be found in this way begin over again with two different leads initially connected together; for example, connect lead *1* of one transformer with lead *2* of the other, and repeat the above proceedure. In this way, try out every possible combination of secondary leads until the proper one is found. If the proper combination can not be found, the two transformers can not be operated in parallel. There is nothing to be gained by changing the connections on the primary side. When two three-phase transformers are designed for parallel operation it is customary to arrange them so that leads similarly located should be connected together for parallel operation. See article on "Parallel Operation," by Mr. J. B. Gibbs, in the JOURNAL for May, 1909, p. 276, and further references on p. 17 of the Seven-Year Topical Index. E. C. S.

554 — Paralleling Transformers — Some tests were made on two transformers of the same size and ratio, but with different magnetic circuits. The impedance volts were found to be 46.8 and 61.2 respectively, taken with the secondaries short-circuited and normal current circulating in the primaries. The resistances of the two transformers, however, taken at the same temperature, by the drop of potential method were found to be nearly equal. Am I right in infering from the article by Mr. J. B. Gibbs in the JOURNAL for May, 1909, p. 276, that the regulation of the two transformers on full or overload would differ materially? R. B. R.

The regulation of the transformers will depend on the power-factor of their load. Since the two transformers have the same resistances, the one which has the greater impedance must have the greater reactance (*impedance*^{2}—*reactance*^{2}=*resistance*^{2}). With a load of unity power-factor, the resistance drop is nearly in phase with the impressed e.m.f., and the reactance is nearly at right angles to it. The regulation is then nearly proportional to the resistance drop, and therefore, if operating in parallel on a load which has a power-factor of unity, the regulation of the two transformers in question will be practically equal since the resistance drops are practically equal. At zero power-factor, however, the resistance drop is at right angles to the impressed voltage and the reactance drop in phase with it. Therefore, with such a load, the regulation will be proportional approximately to the reactance drop, and in the case in hand, the regulation of the two transformers will differ considerably. It should be borne in mind that regulation is no indication whatever of the ability of transformers to parallel. This depends on impedance alone and impedance is a constant, entirely independent of load power-factor. (See No. 441.) While, as indicated above, the regulation of the two transformers at unity power-factor is the same, the impedances are different and therefore the currents in the two will always be different, but will always have the same relation to each other. Thus, the current in the transformer having an impedance of 46.8 ohms, will be 61.2 ÷ 46.8 or 1.31 times that of the other, and this relation will always be maintained regardless of the magnitude or power-factor of the load. Thus the transformer having the lower impedance will take approximately 57 percent of the total load at all power-factors. E. C. S.

555—Transformer Connections — My Company has two cotton mills that are operated by means of three-phase, 550 volt, 60 cycle, induction motors with power from a hydro-electric plant. One of the mills is located 150 feet from the power house, the other about two and one-half miles, and this one is supplied with current from an 11 000 volt transmission line. We have four 600 volt, three-phase generators in our plant but we only gener-

ate current at 575 volts. There is a set of three 500 kw, single-phase step-up transformers in our power house, 600/11 000 volts, and another set at the mill which steps the voltage down from 11 000 to 600 volts. They are connected so as to give 570 volts; these are the voltages we get when the heavy day load is on (2450 kw). At night when we are running at 550 volts at the power house we get 615 volts at the distant mill, which is too high for the lights when the load if off. The transformers are delta-connected at both ends of the line, primary and secondary. Now, could we connect them star on the high voltage sides, and get about the same voltage at both ends, leaving the lower sides delta-connected (that is, could we get 560 volts at the mill two and one-half miles away and generate at 560 volts)? The transformers have four taps on the high side. By star connection we would get about 19 000 volts on the line, then by grounding the center we would only get about 9 500 volts to ground. Could we still use our same insulators? What size wire should be used to ground? Would it be all right to use the lightning arrester ground, or should a separate ground be provided? Would a two-inch pipe driven ten feet deep be satisfactory for this purpose?

W. L. C.

The full-load voltage at the end of the line is stated as 570 volts while the corresponding no-load voltage is 615 volts. If the transformers were star-connected on the high-tension side instead of delta-connected as at present the difference between no-load and full-load voltage (i.e., full-load drop) would probably be reduced in the ratio of approximately 1 to $\sqrt{3}$, that is 58 percent of its present value. Since the problem is one of regulation, it would be necessary to re-connect the transformers to give a lower voltage (approximately 590 volts) at night, i.e., when the load is off; when the load is on the voltage still would not fall below 570 volts, on account of the improved regulation resulting from operating the transmission line at the higher voltage obtained with star-connection of the transformers. There would still be 20 to 25 volts difference between day and night voltages if the generating conditions remain the same as noted in the question. The transformers and insulators would probably stand the extra voltage due to star-connection without difficulty, if the line were properly grounded, but the manufacturers of the transformers and other apparatus affected should be consulted before the change is made. For grounding the line use a wire at least as large as that of the transmission line. It should thus be possible to obtain a ground of not over 30 ohms resistance by using a lightning arrester ground. If not, additional conductivity should be obtained by means of pipes driven into the ground as suggested in the question. If a grounded circuit is employed the practice of grounding the transformer cases should be followed. See Nos. 60, 188 and 492.

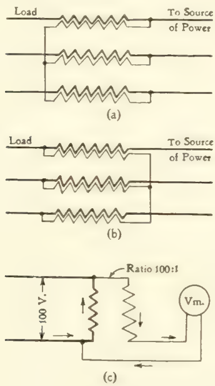
E. C. S. & R. P. J.

556 — Booster Transformer Connections—*a*--Please advise which of the connections shown in Fig. 556 (a) and (b) is correct for star-connected booster transformers? *b*—If a potential transformer of ratio 100:1, and whose polarity is as indicated by the arrows, be connected to a voltmeter as shown in Fig. 556 (c) what will the meter read?

N. V. V.

a—Either of these connections may be employed but different results will be obtained. With the connection given at (a), i.e., when the shunt or primary side of the booster transformer is connected across the line toward the source of power, the voltage of the load side will be boosted an amount equal to the secondary voltage of the booster transformer. With

the second scheme of connections, in which the primary of the booster transformer is connected on the load side of the line, a little higher boost is obtained. If a 2 000 volt source is assumed, the ratio of the booster transformer being 10:1, then the first method of connection will give 2 200 volts at the load and the second con-



FIGS. 556 (a) (b) AND (c)

nection will give approximately 2 222 volts. See Nos. 23, 163, 284 and 320. *b*—A voltmeter connected as shown in Fig. 556 (c) will read 101 volts. This will easily be seen by drawing arrows showing the direction of the current through the windings of the transformer itself. The arrows will indicate additive voltages. A. P. B.

557—Books for Traction Engineer—What are the best books for a traction engineer to have in his library? Books that can be relied upon for data on the various subjects related thereto? What are the best periodicals on this line, either German or English? F. H. W.

Standard Handbook for Electrical Engineers. (Third Edition, 1910. $4.00 net). The section on "Electric Traction" will be found more reliable than the majority of technical books, and the large amount of information that it contains on the general subject of electrical engineering, makes it a valuable book for traction engineers.

Foster's Handbook for Electrical Engineers. (Sixth Edition, 1910. $5.00 net). The same thing applies to this handbook.

Gottshall's Electric Railway Economics. (Second Edition, 1909. $2.00 net). An excellent, broad-gauge book.

Herrick & Boynton, American Electric Railway Practice. ($3,00 net). A good, practical book, especially valuable to operating engineers.

Parshall & Hobart, Electric Railway Engineering. (1907. $10.00 net). This is one of the most comprehensive books dealing with the engineering features of electric railways, and is profusely illustrated. The criticism, from an American engineer's standpoint, would be that it gives foreign railway practice undue prominence and is decidedly partisan. (In this connection note article by Mr. Malcolm MacLaren in the JOURNAL for Aug., 1907, p. 461). The cuts alone, however, would make the book a valuable one for an engineer's library.

The Electric Transmission of Energy, by Arthur Vaughan Abbott (Fifth Edition. $5.00, net), contains valuable information on the design, construction, and installation of power distribution circuits, including underground systems, of importance to traction engineers.

Electric Trains, by H. M. Hobart (1910), contains interesting data on results of operation on several English roads.

Bell's Power Distribution for Electric Railways. (Third Edition. $2.50 net). This book, although somewhat out of date, contains a discussion of the fundamental problem of determining the feeders for electric railways that is especially valuable.

The series of articles on Electric Railway Engineering published in THE ELECTRIC JOURNAL

Jan., Feb., Mar., May, and July, 1906, and July, Aug., Sept., Oct., and Nov., 1908, constitute a valuable treatise on the predetermination of the electric equipment for interurban railways.

The Electric Railway Journal, ($3.00 net), and Proceedings of the American Institute of Electrical Engineers ($5.00 net), and THE ELECTRIC JOURNAL (see Seven Year Topical Index), I consider the best periodicals for the Traction Engineer. The latter contain only occasional articles on railway topics, but they usually make up in quality what they lack in frequency. H. C. K.

558—Effect of Generator Characteristics on Power-Factor—We have recently installed a 400 kw, three-phase, 60-cycle, 6600-volt, water wheel type alternator, and find the power-factor of the load on this new alternator different from that of the same load on our old alternator of the same nominal size and characteristics. The power-factor is supposed to be independent of the generator and to depend upon the character of the load on the generator. If this were a fact it would seem that the instruments, in each case one ammeter on each of the three wires and an indicating wattmeter, must be at fault. Can the inherent characteristics of the alternator effect the power-factor of the line, or is the apparent difference in power-factor due to errors in instruments? O.W.M.

Under no circumstances can the generator affect the power-factor of the line. There is also no apparent reason for the same instruments indicating differently with different generators. We assume that the frequency is the same, that the wave form is substantially the same with the two generators and that the generators are not in parallel with other generators or with each other. If the wave form of the two machines is different, the magnetizing current of the transformers supplying the load will be different in the two cases; a peaked wave form will result in low magnetizing current, while a flat top wave form will give high magnetizing current. (See article on Iron Loss Testing, in the JOURNAL for Apr., 1911, p. 383.) Difference of wave form can also affect the instrument readings, the amount of the effect being determined by the particular type of instrument used. The effect is greater, the lower the power-factor. If the load consists partly of direct-current arc lamps fed through mercury rectifiers, a slight difference in the wave form of the respective generators may be responsible for the change in power-factor which has been noted, as this particular kind of load has the effect of accentuating any tendency toward reduction of power-factor due to peaked wave form, in some cases limiting the capacity of the generators supplying the power. There is a possibility also that the armature winding on one of the alternators in question is slightly unsymmetrical. In this case, with a motor load consisting of symmetrically-wound machines, there will be a certain amount of idle current flowing in the mains which is partly leading and partly lagging, but which may show on the ammeters. If a symmetrically-wound generator is connected to the same circuit, this idle current should disappear and the ammeter readings should be different. On some of the old designs of alternators, the type of winding used was such that perfect symmetry was difficult to obtain. Other than these effects, the power-factor should be the same in the two generators.

F.D.N. AND F.C.

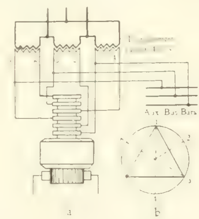
559—Copper vs. Carbon Brushes—Copper brushes are generally used on the collector rings of rotary converters; in the slip ring induction motor with external resistance, carbon brushes are generally used. Please give the reason for this difference. The electrical conditions seem about the same with the exception that, when running under normal conditions, the voltage across the brushes in the induction motor is much less and consequently the power loss greater. A.W.F.

On rotary converter collector rings large currents have to be handled,

and copper brushes are used because they give larger current carrying capacity for a given size of ring than do carbon brushes and less voltage drop at the point of contact; hence, lower losses. Converters of large capacity are often equipped with carbon brushes but in some cases the increased size of rings necessitated by their use may become prohibitive on account of limited floor space, especially in the case of six-phase machines. On the other hand, the advantage of using carbon brushes, when the requirements of design and operation will permit, is the lower renewal cost due to lower first cost and less wear. A compromise is sometimes effected by employing carbon brushes made with layers of copper wire gauze to increase their conductivity; the lubricating effect of the carbon is thus taken advantage of. Carbon brushes may be used to advantage for slip ring induction motors, as heavy currents can be avoided by designing the rotor windings to give sufficiently high secondary voltages. In large induction motors with currents comparable with those in the alternating-current side of rotary converters, carbon brushes are used to a great extent, but in many cases where the motor is intended for steady operation, the collector rings are equipped with a short-circuiting device which is thrown in at full speed so that the carbon brushes then carry practically no current. In this way the higher loss of carbon brushes, compared with copper, is of importance only during starting. On the other hand, the collector rings and brushes of rotary converters must be in circuit at all times and there is necessarily considerably more loss than if copper brushes were used. F.D.N. AND F.C.H.

560—Six-Phase Rotary Converter—In the rotary converter connection diagram, Fig. 560 (a), what is the voltage between the auxiliary busses, and what is their phase relation to the voltage between the secondaries of the transformers? As the converter is supplied by three transformers through six diagonal connections, can it be called a three or a six-phase converter? How are six phases obtained in the converter by supplying it with three-phase current, and how is the armature wound to attain this result? E.K.

The armature taps to which the six alternating-current collector rings of the six-phase rotary converter are connected, are made at intervals of 60 electrical degrees; a three-phase rotary converter would be provided with half this number of taps at intervals of 120 electrical degrees. There are two methods of obtaining six-phase voltage relations from three-phase transformers, viz., by means of the diametrical connection and by means of the double-delta connection. These two methods of connection are given in articles by Mr. H. W. Brown in the JOURNAL for June, '08, p. 347, and Mar., '09, p. 172. See also articles on "Testing" in the Mar. and Apr., 1905 issues, pp. 181 and 249. The connection employed in the present case is the diamet-



FIGS. 560 (a) AND (b)

rical connection. The voltage across lines connecting the rotary converter to the secondaries of the transformers shown are the same as the diametrical voltages of the converter, viz., 430 volts, and are represented in the vector diagram, Fig. 560 (b) by the lines 1-4, 3-6 and 5-2. These voltages must be 0.707 × the direct-current voltage for a six-phase diametrical connection. The voltages on the auxiliary bus-bars are respectively 86.6 percent of the voltage of the secondaries of the transformers and are 30 degrees out of phase with the transformer voltages. They are represented in the vector diagram by the lines 1-3, 3-5 and 5-1. This is the case only when the converter is operating; when the rotary converter circuits are open, the voltages across the respective auxiliary bus-bars are zero.

F.D.N AND H.W.B.

561—Six-Phase Rotary Converters Operated on Two-Phase Circuit—Would there be any special difficulties in operating six-phase rotary converters from a two-phase circuit by means of transformers connected for two-phase—three-phase transformation, provided the proper phase relations and connections to the slip rings of the machines were taken care of before initial operation? What is the proper voltage to be applied to the slip rings? J.H.W.

Comparatively satisfactory operation may be obtained provided a reduction in efficiency and in the capacity of the machines is allowable. The armature taps to which the six alternating-current collector rings of a six-phase rotary converter are connected, are made at intervals of 60 electrical degrees. The three-phase voltages obtained by transformation from the two-phase source of power would be applied to alternate taps, i. e., at intervals of 120 electrical degrees, utilizing only three collector rings. The amount the capacity will be lowered will depend upon the design of the machines, the limiting points probably being the heating of the armature tap coils and taps and of the alternating-current brushes and brush-holders. The losses at the decreased load resulting from three-phase operation would be about the same as the losses obtained when operating under normal six-phase conditions; hence, a corresponding decrease in the efficiency would result. The three-phase voltage which would be required is equal to 0.61 times normal voltage required on the direct-current side of the machine. It should be noted, however, that if the use of double secondaries on the transformers is possible, the equivalent of a six-phase delta connection can be obtained, so that the converter can be operated on six-phases. Also, by two separate sets of transformers, each converting from two-phase to three-phase but with the three-phase end of one set reversed with respect to the other, the double delta could also be obtained and the rotary converter loaded six-phase. One disadvantage in converting from two-phase to three-phase or six-phase as indicated above, is that the wave forms of the different phases on the three-phase side are liable to be somewhat unsymmetical with respect to each other so that symmetrical voltage conditions are not supplied to the rotary converter. In consequence, there may be a tendency for somewhat unbalanced current to flow, so that the capacity of the rotary, either on three-phase or six-phase, as described above, would probably be slightly less than with a true balanced arrangement.

J.B.W. AND T.L.Y.

562—Paralleling Stationary and Revolving Field Alternators—What changes would be required in the field excitation of a composite revolving armature generator of 125 kw capacity to fit it to operate in parallel with a 180 kw revolving field generator. Both are driven by water wheels of the Pelton type. L.W.

In order to operate these generators in parallel it would be necessary to operate the composite wound machine as a separately excited generator. The compensating field winding could be connected in series with the present separately excited field winding thereby adding slightly to the capacity of the latter. However, if the power-factor of the load is much below unity a complete new separately excited field winding of suitable design would be required and the manufacturers should be consulted. Other points to be considered, if uniform division of load between the two generators is desired, are their inherent regulation characteristics and the shape of their respective saturation curves; these points are of importance only when automatic regulation is involved. Otherwise, the division of the load can be regulated by hand, by proper adjustment of the field rheostats of the machines. Proper speed regulation of the water wheels will, of course, be required. J.B.W.

563—Theory of Operation of Three-Phase Generators—Given a three-phase generator, if the three terminals are short-circuited the armature ampere-turns would be approximately equal to the field ampere-turns. Please explain this and state what law governs conditions of this kind. R.F.H.

Assuming that the construction of the armature and field cores and the windings are identical, and neglecting leakage, the ratio between the field and armature ampere-turns would obviously be one to one. On account of the field core having open spaces between poles and on account of the differences in the windings, there is a certain approximate ratio differing from one. Regarding the laws governing this ratio, refer to one of the standard text-books on alternating-current generator design, as space limitations prohibit a comprehensive discussion of the subject here. It may be stated in brief, however, that on short-circuit the armature current will necessarily rise to such a value that it tends to overcome or neutralize the field producing it. If the armature and field windings were similarly disposed or distributed with respect to each other, then the armature ampere-turns, when equal in value to the field amper-turns, would exert an equal and opposite magnetizing effect, and thus the magnetic field tending to generate such armature current would be destroyed. Obviously the armature current could not quite reach this value. In practice, however, the armature coils are distributed over a surface so that their combined magnetizing effects are not directly super-imposed. In consequence, the apparent armature ampere-turns may considerably exceed those of the field, although the resultant magnetizing effect of these armature ampere-turns must necessarily be slightly less than those of the field, as explained above.

J.B.W. AND B.G.L.

564—Commutator Troubles—The brushes on one of our direct-current machines scratch the commutator pretty badly even after a day's run. We have tried numerous remedies with non-success. The carbon does not seem particularly hard, the brushes are carefully ground and set and the tension is not more than two lbs. per square inch. Please enumerate the causes that might lead to such trouble. H.G.H.

We would suggest that you try a type of brush possessing self-lubricating properties. These may be obtained from various manufacturers of carbon brushes whose advertisements are to be found in electrical periodicals and trade journals. In consulting the manufacturers regarding such a problem information should be furnished regarding diameter of the commutator of the machine, number of commutator bars, speed, number of brushes per brush arm and number of brush arms. Note article on "Problems in Commutation" by Mr. Miles Walker in the JOURNAL for May, 1907, p. 276, and editorial on p. 243; also, QUESTION BOX references on p. 11 of The Seven Year Topical Index. W.A.D.

565—Difficulty with Parallel Operation of Motor-Generator Sets—We have two motor-generator sets, each consisting of a 250 kw direct-current shunt generator, with commutating fields, and a squirrel-cage induction motor. One is of European construction and the other of American make. When it was attempted to run them in parallel the load seemed to oscillate from one to the other and the voltage became so abnormally high that one of the circuit breakers would be opened. The above phenomena only occurred when an attempt was made to shift the load, the generators operating in parallel satisfactorily when the switch was first closed. Can you advance an explanation? H.G.H.

In order that two direct-current machines shall run properly in multiple, it is necessary that they have the same characteristics as to regulation. It is probable that the machines have different inherent regulating characteristics. Such difference can be obtained on interpole machines by giving the brushes a lead. A backward lead will tend to raise the voltage and a forward lead to reduce it. To

parallel properly, two direct-current machines, either shunt or compound, must have an inherent tendency for the armature voltage to drop with increase in load. This naturally causes each machine to tend to shift its load to the other machine, and neither tends to take more than its share, so that stability is thus obtained. With interpole machines and a wrong setting of the brushes, the inherent armature regulating characteristics may be such as to give a constant, or even a rising, voltage and one machine may try to take more than its share of the load, so that stability is not obtained. An increased forward lead on an interpole generator tends to give a drooping voltage and greater stability. With such a change, however, the interpole field strength may require adjustment. We suspect the trouble in the present case is that one of these machines has its brushes set with backward lead so that its characteristic is different from the other. The best way to try this out is to run each machine separately, varying the load and making adjustments until both give the same voltages with the same loads. If the two direct-current machines have inherently about the same regulation and the alternating-current motors driving them have a considerable difference in their slip with increase in load, this might also account for trouble in paralleling, although we believe that, unless the slips are widely different, no particular trouble will be experienced from this source. W.A.D.

566—Equalizer for Paralleling Direct-Current Generators—A 200 kw, 250 volt, direct-current generator is to be operated in parallel with a 400 kw, 250-volt machine located 200 feet distant. What size of equalizer should be used? If any articles bearing on the subject of parallel operation on machines of unequal size have appeared in the JOURNAL please give references. L.H.G.

It is customary to use the same size of leads for equalizer as for mains, to secure a low resistance connection. For articles on parallel operation see the Seven Year Topical Index, p. 12. Note especially article by Mr. H. L. Beach, Nov., 1909, p. 681. W.A.D.

567—Progressive vs. Retrogressive Wave Winding—What advantages, if any, are possessed by a progressive over a retrogressive wave winding? I have observed that the standard practice of one company, for example, is to use a progressive winding. For instance, in an armature with 47 slots and 47 commutator bars and having coils laid in slots *1* and *11*, the coil leads are connected to *1* and *25*. If they were connected to 1 and 24 instead, the end connections would be a little shorter and the armature resistance therefore slightly lower. A.C.J.

There is no advantage in a progressive over a retrogressive winding except a small difference in length of connections as noted. It should also be noted that winding progressively or retrogressively will determine the direction of rotation of an armature, other conditions remaining constant. The progressive winding is probably adhered to merely for the sake of standard practice. In fixing a practice, both parallel type or lap windings should be considered as well as wave windings. The arrangement chosen might show enough advantages in lap windings to overbalance any disadvantages as compared with other windings. W.A.D.

568—Flat Spots on Commutator—I have a ten hp, 220-volt direct-current motor on which the commutator has become flat. Please advise regarding cause and remedy. B.F.G.

Among the several possible causes of flat spots on commutators may be mentioned: Brushes sticking in holders; unequal spacing of brushes or poles; a bad belt, splice, broken gear tooth, or anything which will give the armature a series of jolts or jars. An armature having an idle coil will sometimes develop a flat spot. The cure is to turn down the commutator and correct any of the above conditions which may exist. It is also helpful in some cases to undercut the mica in the commutator. J.M.H.

THE
ELECTRIC JOURNAL

Vol. VIII JULY, 1911 No.7

Continuous Electric Service

The value of continuity in electric service is difficult to estimate, particularly as it varies under different conditions. To the operating company, interruption of service for a few minutes or a few hours may mean simply a loss of revenue, or it may mean also loss of prestige and the confidence of the community, or it may involve rebates or damages to be paid to its customers in addition to the cost of repairs to its own apparatus. To the user of electric power an interruption may mean little or it may mean much. If a motor is pumping water into a reservoir and runs only a part of the time, a short interruption may have no effect upon the water supply which the reservoir affords. In other cases momentary loss of current may be a matter of simple inconvenience. Again, if a motor is running an automatic machine, the loss is proportional to the length of time that the machine is idle. In most cases, however, the loss is far greater than the loss of time or the cost of the electric power. In manufacturing operations where power is essential to the operation of machinery and the performance of workers, the cost of the power is only a few percent of the total cost. Hence, an interruption of a few minutes, during which time the power might cost a few dollars, may prevent the making of several hundred dollars worth of product. Sudden darkness in an electrically lighted store may prevent many promising sales. Furthermore, in certain operations, interruptions in electrical service may be followed by very serious consequences. If the hot metal which is being rolled in a steel mill becomes chilled while the rolls are stopped, or if the presses of a daily newspaper stop for half an hour at a critical time, or if the fans or pumps which serve a mine are idle too long, the loss may far exceed the cost of power for a whole year.

Continuity of service means much more now than it did years ago on account of the larger and more responsible work performed by electricity. The dependence upon electric current due to its increasing use in the industries, in transportation and for general domestic purposes, will place an increasing value upon continuity.

In fact, the supreme test of the central station as a means of supplying power for all purposes, including heavy railway service, may depend even more upon its ability to give good service than upon the actual price per kilowatt-hour.

The basis upon which continuity depends is, first, an engineering knowledge of the apparatus and methods which can give good results, then, the installation of these appliances in the best possible manner, and, lastly, the intelligent operation of the system. Now the engineering knowledge as to what apparatus is best, is the result of the work of the designer and manufacturer on one hand, and the experience of the operator on the other. The two—knowledge and experience—must go together, evolving the larger and better apparatus which the progressing needs of central stations and transmission systems demand.

If reliability, as well as kilowatt-hours delivered, is a measure of the value of electric service, a company can afford to install only the very best quality of apparatus. The engineer of one of the largest central stations in the country has stated that the policy of his company was to demand of its engineers the very best possible plant. In case of breakdown, the engineer could not say it was due to cheap apparatus or to apparatus cheaply installed; the engineer was at fault if other than the best work had been done.

Even the best possible plant must be intelligently operated. When an unavoidable accident occurs its effects may be relatively small if the operating force is competent and alert. "Reliable Electric Light and Power Service" is the heading of a conspicuous statement, displayed in the advertising columns of a large Eastern daily, a few days after a fire early one morning in one of the main distributing stations, which seriously disturbed the electric supply of the city. In its statement the company explains that through the coolness and efficiency of its men, the fire was put out and the electric current cut off without serious injury or loss of life; inside of half an hour the entire machinery of a large organization was put in motion to furnish current to the customers who were affected; hundreds of feeders and cables had had their insulation partly destroyed and were covered by debris and completely flooded by water, and fuses and catches in junction boxes through the central district of the city had been blown, and the disconnection of the injured feeders and the reconnection of feeders and mains from other sub-stations had to be made; by ten o'clock, four and one-half hours after the fire occurred, thirty percent of

the affected district was connected, by noon fifty percent, and by evening all but a very small percent were receiving approximately the normal service; the serious accident did not affect public service institutions, while theatres gave performances and newspapers were published as usual. The company adds that no other source of power or lighting supply, except that furnished by a large central station backed by a large,resourceful and efficient organization, could be so secure or so well safe-guarded against interruption.

This public statement emphasizes two things:—Reliability, and efficient organization. It further shows the ability of a resourceful management to turn disaster to triumph by advertising to the public that the accident actually substantiates its claim for reliability.

Of the many articles which have appeared dealing with continuity of power service from one standpoint or another, few are more comprehensive and well considered than the present one by Mr. R. P. Jackson. It presents in a lucid manner the common elements which tend toward interruption of service, and is a valuable contribution to this most important subject. CHAS. F. SCOTT

New Business Reports

At the present time the great majority of the manufacturing plants which can eventually be supplied with power from a central station, require very careful presentation of all the facts, both engineering and commercial, regarding the power supply before the manager of the plant can be interested in purchased power. The number of cases where a manager voluntarily comes to a central station and states that he wishes to buy power, are very few indeed. Therefore, some form of engineering report on the possibilities of supplying power from a central station must be presented before any real business can be expected. Many central stations have prepared regular reports of various forms. One form of report, which has been found to be particularly satisfactory, is presented by Mr. Perry in this issue of the JOURNAL.

Wherever possible, it is a good plan in making out reports to arrange the summary of costs of steam drive and motor drive side by side in tabular form, so that the costs can be compared item by item. In this way it can be seen at a glance just where the differences in cost lie, whether under interest and depreciation or some other items. It may be mentioned here that great care should be exercised in preparing these two items since they are

bound to be closely scrutinized by the prospective power user.

These reports form not only a very satisfactory means of presenting a proposition to managers of industrial plants, but they also afford an excellent means of interchange of information among central stations. In many localities there is but one industry of a given kind in the territory of a single central station. Hence, the work required on the part of the central station engineer is all original unless he is able to draw on the experience of other central stations that have similar industries in their territory. It is to be noted particularly that the central station benefits by such interchange in a way not possible in industries covering a wide territory, because, in general, central stations are in no way competitors of each other. When they supply information to other central stations, they in no way decrease the consumption of their own product, but rather help to build it up, as the effect of increase of load is cumulative, not only for the station supplying the increase, but also for central stations in general.

It is to be hoped that all central stations will adopt some such form of report, and that they will also develop some method of interchanging these reports, either through the commercial section of the National Electric Light Association or in some other suitable manner.

S. A. Fletcher

Rating Apparatus by Performance Curves

Several years ago a sub-committee of the Standards Committee of the American Institute of Electrical Engineers undertook to revise a paragraph specifying the method of rating railway motors. Two meetings were held, beginning in the middle of the afternoon and continuing until seven or eight o'clock in the evening, at which engineers, prominent in electric railway work with manufacturing and operating companies and as consulting engineers, discussed the matter from all points of view. Many advocated the one-hour rating and there was long discussion as to the conditions under which tests should be made. Others pointed out that motors which might give equal performance under tests at a certain speed for a certain time might differ widely in their capabilities at other speeds and under tests of long duration. It was urged by some that capacity tests should be made under actual service conditions with varying speeds and varying grades. It was proposed by some designers that the method should be by curves showing losses and thermal capacity, and by others that a fair value of the continuous capacity of a motor might be

determined by a continuous test at an assumed average speed instead of by a one-hour test. All seemed to be disagreement and confusion. Instead of approximating a simple statement of rating which it was anticipated the railway experts could determine when once they got together, it was found that such a result seemed more and more impossible of attainment. It was then suggested that the deliberations of the Committee probably exemplified the actual conditions, namely, that there was no such thing as a simple, satisfactory rating, but that a motor which must operate under a wide range of conditions must have its capacity for meeting all these conditions presented, if an adequate knowledge of its capability is to be stated. It was, therefore, proposed that the outcome of the Committee's work, instead of being a simple definite formula, should be, in fact, a statement of its deliberation which would present the facts that make any simple, nominal rating impossible, and should further present an outline of the requirements which a motor must meet for a specific service and the different methods used by engineers in selecting a motor for a specific service. Such a statement was prepared and now appears as Appendix "B" of the Standardization Rules. The horse-power rating of a railway motor is now either done away with entirely, or serves merely as a convenient name, rather than as a rating which is to be used in determining whether the motor is suitable for a given service.

In the designation of alternating-current generators the conditions are in some respects similar to those of railway motors. There is scarcely any one feature in the specifications of electrical apparatus which has been more evasive and has cost more vexatious disappointment than the failure to understand the relation between the power-factor of a load and the capacity of the generator. The situation is even harder to deal with than the rating of a railway motor, because the generator is connected to an engine which has a definite power rating. The temptation, therefore, is to give the generator an equal rating and to overlook effect of power-factor.

Granting that a given generator has a different kilowatt and a different kilovolt-ampere capacity for 100 percent power-factor, for 90 percent power-factor, for 80 percent power-factor and for 70 percent power-factor, why should an attempt be made to describe the machine by designating a single condition? Again, if the size of the generator to be driven by an engine of 1 000 horsepower is determined by the power-factor of the load, and is different for loads of 100, or 90, or 80, or 70 percent power-factor, why not designate generators in such a way that the exact con-

dition can be known and specified? Just as it has become common to set forth the capability of a railway motor, and, in fact, series motors in general, by certain speed-torque and time-temperature curves, why is it not rational also to indicate the capability of an alternating-current generator by a table or curves showing its permissible output in kilowatts and in kilovolt-amperes at different power-factors? This method has been tried, and is found to go far toward clearing up the power-factor mystery, which is so persistent among those who are not familiar with the fundamental relations, and it would make smoother and more definite the work of those who understand the principles and want to know the facts in a particular case.

Furthermore, as the applications of electricity become more specific and motors for variable service must be applied within closer and closer limits for variable and intermittent loads, the facts as to their characteristics cannot be satisfactorily expressed by some simple rating, but some means must be adopted which will definitely and clearly indicate their performance under different conditions of operation and service. CHAS. F. SCOTT

Newspaper Load For Central Stations

One of the essential power requirements of city newspaper plants is continuous service. The cost of energy, while important, is subordinate to production. It is significant in view of this fact that so many of the newspapers in large cities secure their power from the central station. Modern transforming, transmission and switching apparatus have been brought to such a condition of reliability that the central station can bring power from considerable distances and deliver it with greater reliability than can a plant of few units and small reserve capacity located on the premises.

The wide range of speed required by cylinder presses, together with the necessity for frequent starting and stopping make mechanical drive from steam or gas engines extremely difficult, so that electric drive has become almost universal.

A feature of the installation at the *Pittsburg Press,* described by Mr. Breed in this issue of the JOURNAL, which is worthy of especial note is the use of synchronous apparatus in the sub-station in the building, and the installation of a graphic recording meter, by which continuous records of power-factor variation are obtained. The adverse effect of low power-factor upon the capacity as well as the voltage regulation of a system is well known. The fact that

modern generators, transformers, etc., are rated in kilovolt-amperes rather than kilowatts should make this evident even to the casual reader. The value to the central station of apparatus which can furnish a load of unity power-factor or with a leading power-factor is becoming more and more appreciated. Such a load is especially desirable if it is suitably located and the time during which the apparatus is in use coincides with the time when power-factor correction is most needed. After the evening lighting peak goes off, the load on the average station consists largely of transformer core losses and either constant-current arc regulators or induction motor-driven arc machines, all of which tend to produce a low power-factor. Also during the day industrial loads commonly consist of induction motors operating at fractional loads, and thus causing low power-factor. Installations of synchronous apparatus operative at either or both of these periods are, therefore, worth cultivating, and if located on over-loaded feeders having poor voltage regulation are worth considerable effort to secure. In some cases it may be worth while to make it to the advantage of the consumer to maintain the power-factor which will give the greatest corrective effect.

By securing a sufficient amount of such load a considerable increase in revenue-producing station and distributing capacity can often be secured. In the knowledge of the writer, loads which could easily have been driven by two engines required the connection of a third generator to carry the current of the low power-factor load. The use of three engines, each lightly loaded, necessarily resulted in poor engine efficiency.

While the cost of power in newspaper work is not as important as in some industrial operations, the central station rate should not exceed that which could be attained by a private plant. On account of the long hours of operation and fairly uniform load, newspaper plants should secure a fairly low rate since their period of operation seldom overlaps the peak load on the station. It is unnecessary to enter into a discussion of the economies that can be secured by selling power during the off-peak period at a rate but little greater than the additional fuel, oil, waste and labor required. One point, however, that is often overlooked is that any such off-peak loads serve to decrease the overhead charges per kilowatt-hour output, because of their effect in improving the twenty-four hour load factor, and thus increase the profit on the peak load business. This is only another angle from which to view this much discussed problem.

H. N. Muller

ELECTRICAL FEATURES OF AN UP-TO-DATE NEWSPAPER INSTALLATION

L. B. BREED

THREE thousand twenty-page newspapers per minute, printed in two colors, pasted, cut, folded and deposited in piles of fifty each, is the capacity of the five big Goss presses in the new Pittsburg Press Building, which print over 100 000 copies per day in seven editions, the printing operation forming the final stage of a process which is keyed to the highest speed throughout. The Pittsburg Press has recently taken possession of its new fire-proof five-story building, which was erected on a lot 80 by 100 feet long, facing Oliver Avenue, near Wood Street. Here has been installed a complete and modern newspaper plant, including every labor and time-saving device known to the newspaper world.

From the blue pencil of the editor to the arm of the newsboy, every mechanical process is carried on by motor-driven apparatus. Power is secured from a sub-station in the basement, where alternating current, furnished by the Allegheny County Light Company at 2 200 volts, is transformed to direct current at 110 volts. The four motor-generator sets, shown in Fig. 1, consist of six-pole, self-starting synchronous motors, directly connected to compound-wound direct-current generators, two of which have a capacity of 100 kw and the others a capacity of 50 kw each.

The motors are provided with a squirrel cage starting winding and are started from low-tension starting bus-bars, fed by two 2 200 volt, 165 k.v.a. auto-transformers. As the machines are not started from the direct-current end, no synchronizing apparatus of any kind has been provided. The excitation for the motors is taken from the direct-current bus-bars. To secure a uniform power-factor, the compounding of the generators has been adjusted to give a rise in voltage, as the load comes on, of about 15 percent. The power-factor on the motors thus remains practically constant over a wide range of load without adjustment of the rheostats.

In addition to the usual instruments, the switchboard is provided with integrating wattmeters to measure the total alternating and direct-current power. A graphic recording power-factor meter is also mounted on the switchboard to record the power-factor, and the excitation of the synchronous motors is adjusted so as to maintain the power-factor desired. Two polyphase meters, con-

nected in series, are used on the main supply circuits, their readings being averaged.

One of the interesting features of this installation is the large amount of apparatus that has been crowded into a very limited space. As shown in Fig. 1, a 14-panel switchboard, four motor-generator sets and four auto-transformers are installed in a room 18 by 34 feet in such a manner that all parts of the apparatus are readily accessible for cleaning and for repairs. There is room at the front of the board for manipulating switches and reading the instruments, and room to work at the rear of the board without

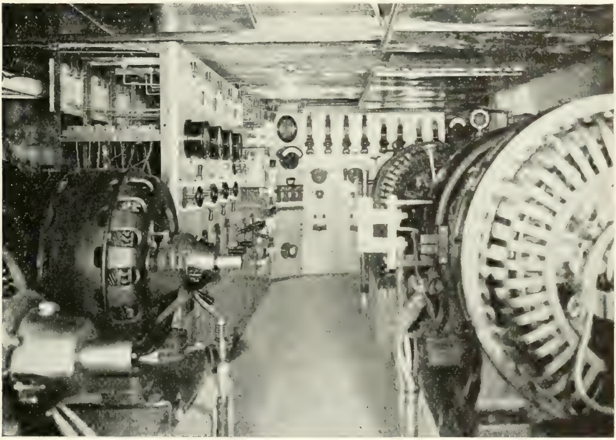


FIG. 1—SUBSTATION FOR TRANSFORMING ALTERNATING CURRENT FROM 2 200 VOLTS, 60-CYCLES, 2-PHASE TO 110 VOLTS DIRECT CURRENT

danger of contact with live circuits. To provide against any possibility of breakdown, two circuits at 2 200 volts, two-phase, and an additional circuit at 2 200 volts, single-phase, are brought in from the central station lines. Direct-current connection is also provided with a nearby private power plant of considerable capacity, at 110-220 volts, three-wire, the distributing circuits for light and power being so arranged that they can be balanced on the three-wire system. As the basement, in which the motor-generator sets are installed, is below the high-water level at times of unusual floods, a waterproof wall has been built around the entire sub-station, and

as additional precaution, a three-wire circuit is run to a panel in the press room, which is entirely independent of the sub-station. The power for the motors throughout the building is direct-current, and the lights and electric matrix driers are single-phase, alternating current.

In order to include the latest news items, stock quotations, baseball scores, etc., it is absolutely essential that the maximum speed be maintained throughout the various operations, and no expense has been spared by the management to secure this end. These operations may be divided into five main divisions: 1—securing the copy; 2—setting the type and locking it into the form for the page; 3—preparation of the matrix; 4—casting, trimming and cooling the stereotype plates; 5—inserting the plates in the presses and printing the several editions.

THE EDITORIAL ROOMS

On the second and third floors all copy for the compositors is prepared, the business and advertising rooms being on the second floor and the editorial rooms on the third. Here, by telegraph and telephone, the dispatches are received from the outside world, and all local news is prepared by the reporters, whose individual typewriter desks face those of the city editor, the Tristate news editor and copy reader. Nearby is the desk of the telegraph editor and of the news editor, who places the stories and arranges page make-up.

In adjacent rooms are the offices of the sporting editor, the financial editor, the Sunday editor, and the various special writers. In special rooms also are the librarian, and the keeper of the "morgue." This latter is quite an institution in itself, as it includes two rooms filled with cases in which are filed biographies and photographs of almost everyone likely to be heard of in the world's events.

In order to facilitate passing of copy through the various mechanical processes, all of the departments are arranged so that the material passes through them in logical order and with the least handling. The typewritten copy from the editorial rooms is conveyed to the composing room on the fifth floor by means of a motor-driven carrier, which deposits it automatically at any designated station. This carrier is similar to those used for carrying change in stores but, instead of boxes, is fitted with sets of steel fingers

designed to hold a standard envelope. The release mechanism is arranged so that an envelope can be dropped and another picked up from the same station by the same set of fingers.

THE COMPOSING ROOM

The actual setting and arranging of the type occurs largely in the composing room on the fifth floor. The typesetting for much of the advertisements and for all of the news is performed by 25 linotype machines, each driven by a small motor, which cast the type, a line at a time, from delicate brass matrices or moulds, and automatically trim and cool the slugs. They are operated, as shown

FIG. 2 GENERAL VIEW OF LINOTYPE MACHINES

This view includes about half the machines on this floor. Each machine is individually motor driven.

in Fig. 2, from a keyboard somewhat like that of a typewriter, and at about the same speed, being provided, however, with a very much greater range of characters than any typewriter, while by changing the magazine, which can be done in less than a minute, an entirely different size, or font, of type may be used. With one of these machines, a fast operator can set 2 400 words per hour in small sized type.

The battery of linotype machines almost surround the copy-cutter, who receives the copy from the editorial rooms, sorts it as to the style of type to be used, and assigns it to the various

operators. All of the ordinary reading matter is set by the linotype machines. The display type for advertisements, headings, etc., is set by hand. A monotype machine, casting the type one at a time, is provided, on which a considerable portion of the display type is cast, and a slug casting machine provides all necessary leads. Two motor-driven, automatic inking, proof presses are provided for pulling proofs.

After the proof has been read and corrected by the proof readers and editors, the type is laid out on a stone in the position it will occupy on the finished page, cuts, rules and headings are arranged in position, and the whole is locked in a heavy steel frame, or chase. One of the features of the *Press* equipment is the size of the make-up table, where eight pages are assembled simultaneously by half a dozen men.

Large windows on three sides of the room, and large skylights, all with northern exposure, provide abundance of daylight under ordinary circumstances. General lighting is provided for night work, and in addition the linotype operators are provided with individual lamps, while linolite lamps shielded from the eyes by the space racks, furnish illumination for the cases of the hand compositors.

PREPARATION OF THE MATRIX

In a cylinder press, such as used in newspaper installations, the impression on the paper is made by a metal plate whose surface is identical with that of the type in the form, but is curved, and is clamped to the revolving cylinders of the press. To make this plate, a mould is necessary, of such a nature that it can be made from the type in the form, and can be bent to cylindrical shape before the cast is made. Such a mould, called in newspaper work a matrix, is formed by pasting to a sheet of special heavy moistened pasteboard, a number of successive sheets of close-grained tissue paper. While still moist, this sheet, or flong, as it is called, is laid over the form of type, and rolled under heavy pressure in the motor-operated matrix roller into intimate contact with the type, the fine, smooth surface of the matrix taking the exact shape of all the minute inequalities in the surface of the type and cuts. It is then covered with a heavy felt blanket, which has been previously thoroughly dried and heated, and is shoved into one of the electrically heated matrix driers, the blanket serving to absorb the

moisture. A uniform pressure is then applied by means of compressed air while the matrices are drying. Automatic regulators maintain the temperature of the heater at a constant value, only slightly below the melting point of the type metal. Thermometers showing the temperature of the matrix, and pressure gauges showing the air pressure in the cylinder are connected to each machine. Two minutes are required to dry the matrix on a page of comparatively solid type without half-tone cuts; three minutes for a page with cuts, and four minutes for a page containing large open spaces, such as a full-page advertisement. The blank spaces in the dry matrix are filled in on the back to prevent the pressure of the type metal from flattening them while the cast is being made. An automatic air compressor driven by an 8.5 hp motor supplies compressed air for the tables, starting up when the pressure drops to fifty pounds and cutting off when it reaches seventy-five pounds.

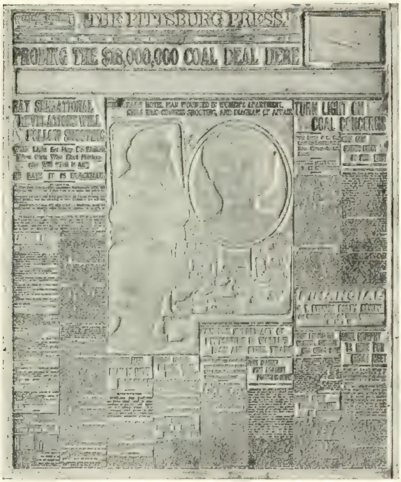

THE PITTSBURG PRESS
PROBING THE $18,000,000 COAL DEAL HERE

FIG. 3—MATRIX USED IN CASTING THE STEREOTYPE PLATES

This matrix was dried on one of the electric matrix driers, and was used in casting the plates for a regular run before this cut was made. The blank spaces at the top are left to be filled in with red ink by another plate.

In addition to using the fastest known wet matrix process, a dry mat process has been devised by means of which a finished matrix may be obtained in less than 10 seconds. The mat is placed over the form and rolled in the same manner as the wet mats, its advantage being that no subsequent drying is necessary. This process is at present used by the *Press* only when exceptional speed is necessary, such as extras, large issues, etc., as the wet process with the electric matrix driers is much less expensive. With the dry mat process a time

of two minutes has been attained from the locked form in the composing room to the finished plate in the press room.

THE STEREOTYPE ROOM

From the composing room the matrices are dropped down a chute to the stereotype room on the floor below. This room is so arranged that the material can pass through it at maximum speed. The matrices are trimmed to exact dimensions in the matrix shears and inserted in one of the two casting chambers of the casting machine shown in Fig. 4. The casting chamber is of cylindrical shape, and is arranged to hold the matrix firmly in position, bent

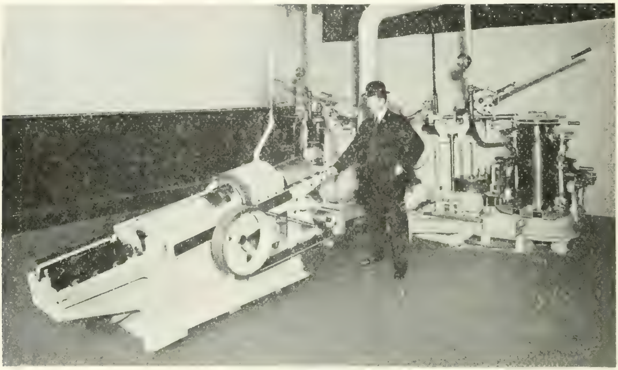


FIG. 4—DOUBLE JUNIOR AUTOPLATE AND AUTOSHAVER*
For casting and finishing the plates from which the papers are printed.

to the exact shape necessary for the face of the plate. The casting chamber is then closed, and type metal is run in from a large melting pot, located at the center of the machine. When the metal has solidified, the casting chamber is opened, and by means of a clutch, the mechanism is started which saws off the ends, trims and delivers the plate. The superfluous metal which has been trimmed off is returned to the melting pot. Eight plates are ordinarily cast from each matrix, thus providing the two plates necessary on each press for each page. The matrices are, of course, saved for possible use in the later editions of the same day. The double auto-plate

*This illustration is reproduced through the courtesy of the manufacturers, The Autoplate Company of America, New York City.

machine has two casting chambers, each being operated independently by a 7.5 hp motor, and having a capacity of three plates per minute.

From the plate casting machine the stereotype plates are taken to the auto-shaver, shown in the foreground in Fig. 4. Here the inside of the plate is shaved to the proper thickness, the ends and edges are trimmed, the plate is cooled by jets of water and all metal chips removed from the inner surface by means of revolving brushes. This process is automatic and continuous, the capacity of the machine being six plates per minute. The plates are now ready for the press and are sent to the ground floor in one of two plate elevators, each having a capacity of six plates. The elevators are motor driven, the control being entirely automatic by means of push buttons. A system of lamp signals is used to announce to the press room employees that plates are on the way.

The color plates, on account of the large area on the plate which does not take ink, must have a considerable part of their surface routed off. This is done by a small routing tool turning at a speed of 12 000 r.p.m. and driven by a two horse-power motor. By reason of the high speed of the flying metal thrown off by the router, these machines are completely enclosed with a fine woven wire screen and the operator is compelled to wear a face mask.

The amount of work done in the stereotype room may be judged from the fact that a twenty-page edition requires for the four presses 160 plates for the main paper, and 16 color plates for the headings. As these plates weigh 65 pounds each, 11 440 pounds of stereotype metal is required for each edition.

The photo-engraving rooms are also located on the fourth floor. To save time and to insure proper working conditions, all photographic work in these rooms is performed by means of artificial light. The photographs are copied in one of two copying cameras by means of an eight ampere enclosed arc lamp with a parabolic reflector on each side of the camera. The printing on the zinc plates is accomplished by means of a twenty-five ampere open arc with aluminum parabolic reflector. These arc lights, together with a 15 ampere arc used by the staff photographer, have an average consumption of about 20 kilowatt-hours per day.

All line cuts must be routed out wherever a considerable open space occurs between the lines. A small motor driven router is provided for this purpose and a small circular saw for trimming

the cuts. The cuts are backed with type metal in the stereotype room. Here also is provided a shaver for reducing the thickness of the cut to the exact height of the type, a circular saw, a band saw, and a trimmer, all adapted to the cutting of type metal.

THE PRESS ROOM

The presses are located in the first floor on brick piers built up from the basement. Between the piers and under the floor, steel I-beams set into the piers from supports for the motors, which are geared to the presses. There are five Goss presses installed in this plant, four of them being five and one-half decks high and used for the daily output, while the fifth is four decks high and is used to print the colored supplement, covers, etc., for the Sunday edition. The capacity of each of the large presses is 18 000 forty-page papers or twice this number of twenty-page papers per hour, with two of the twenty pages printed in two colors.

In order to secure the wide ranges of speed, and the operation at very slow speeds, which is essential at times, two motors are used, a 7.5 horse-power compound motor, with a normal speed of 975 r.p.m., driving the press at slow speeds through a large gear reduction, while at high speeds, the press is driven by a 50 horse-power interpole motor with a speed range of 700 to 1 050 by shunt field control. The motors are operated by the Kohler system of control. A wiring diagram of one of the control panels is shown in Fig. 5, the control for each of the presses being entirely separate. The presses are operated entirely from the push button stations, eight of which are located on each of the large presses at points most convenient for the operators. In addition, by means of a commutating device on the panels, the regular push button stations can be cut out and the presses operated from an auxiliary station located at the center of the press on the lever side.

The press can be started or stopped and the speed adjusted to any desired value from any one of the push button boxes. On pressing the *On* button the press starts and continues to accelerate so long as this contact remains closed. When the pressure is removed from this button, the motor will continue to operate at a constant speed without further acceleration. Any speed from the slowest to the fastest may thus be readily secured. Pressing the *Off* button causes the press to slow down gradually. As in the case of the *On* button, when the finger is removed, the press will continue to operate without further change in speed. Pressing the *Stop* button, opens the motor circuits and applies a dynamic brake, bringing the

press to a quick stop. This button is used in case of emergency. All changes of speed are accomplished gradually and without the slightest jerk or jar. When dressing the press for a run the cylinders may be revolved slowly and brought to any desired position, a movement of as little as one-eighth of an inch being readily made.

TABLE I—MOTORS INSTALLED BY PITTSBURG PRESS

Number	Horse-Power	R.P.M.	Driving
		FIFTH FLOOR	
25	1/6	1 016	Linotype Machines
1	3	1 170	Matrix Roller
1	1/4	800	Monotype Machine
1	1/6	1 016	Linotype Slug Caster
2	1/2		Proof Presses
1	1		Circular Saw
		FOURTH FLOOR	
2	7.5	1 050	Junior Auto Plate
1	3	1 100	Auto Shaver
2	2	1 100	Curved Router
1	1/2	1 350	Stirrer Motor
1	5	1 000	Tail Cutter and Shaver
1	2	1 200	Trimmer
1	2.5	450	Band Saw
1	2	1 150	Plate Shaver
1	8.5	875	Air Compressor
1	3	1 400	Tail Cutter
1	5	1 500	Curved Shaver
1	2	1 600	Royle Router
2	2	1 200	8-inch Circular Saw
4	8 amp.		Enclosed Arc
1	25 amp.		Open Arc
4	1/7		Ventilators
		FIRST FLOOR	
5	50	700-1 050	Presses
5	7.5	975	Auxiliary on Presses.
		BASEMENT	
1	1		Ventilator
1	2	1 600	Baling Machine
1	8.5		Air Compressor for Ink Tank
2	150	1 200	Synchronous Motors
2	75	1 200	Synchronous Motors
2	100 kw	1 200	D. C. Generators
2	50 kw	1 200	D. C. Generators
		ELEVATORS	
1	15		Passenger Elevator
1	10		Freight Elevator
1	5		Sidewalk Elevator
2	7.5		Plate Elevator
5	5		Paper Hoists
74	**435**	**Total outside of substation**	

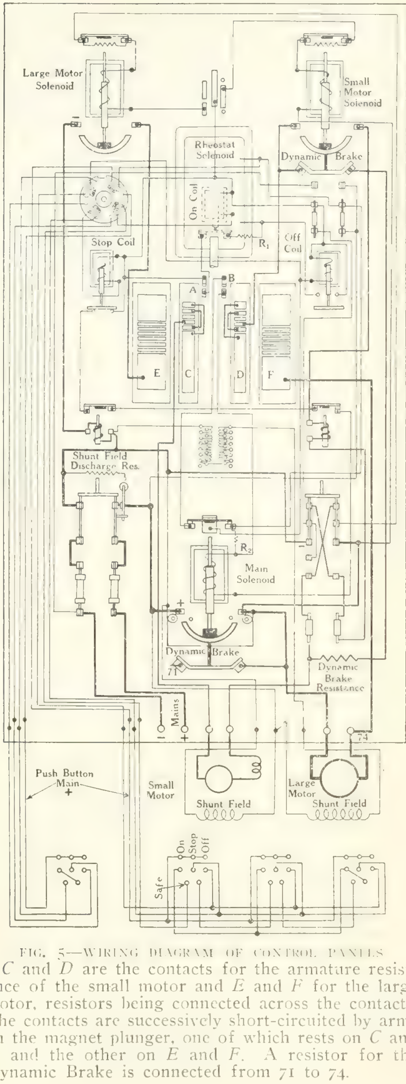


FIG. 5—WIRING DIAGRAM OF CONTROL PANELS

C and *D* are the contacts for the armature resistance of the small motor and *E* and *F* for the large motor, resistors being connected across the contacts. The contacts are successively short-circuited by arms on the magnet plunger, one of which rests on *C* and *D* and the other on *E* and *F*. A resistor for the Dynamic Brake is connected from 71 to 74.

When plating the cylinders or performing any other operation requiring personal contact with moving parts of the machinery, each workman protects himself from injury by pressing the *Safe* button at the bottom of the nearest push button station. This renders all other push button stations inoperative for starting until the *Safe* button is released by pressing the *Run* button at the same station. The *Safe* button may also be used while the press is in operation to prevent further acceleration, as with this button closed at any station the press can be slowed down or stopped from any other station, but cannot be speeded up or started again from rest, until the *Safe* is released.

As a further precaution, and as a warning to the operators, a push button has been placed near

each of the operating stations, which, by means of a solenoid, operates a set of contacts in the circuit leading to the lamps on the press. On pressing the button, the lamps all over the press flicker rapidly, giving warning that the press is about to be started.

As shown in the wiring diagram, Fig. 5, the controller is entirely automatic, and is so arranged that acceleration is smooth and rapid. All speed changes are produced by the action of the rheostat solenoid. The plunger of this magnet is normally retained in its position by a small pawl and ratchet, which prevents movement in a downward direction. The operation of the *On* coil releases the pawl, allowing the plunger to drop, its action being restrained by a dashpot, which can be adjusted to give any desired rate of motion. As the plunger descends, the small motor is started through the closure of the small contacts at the top of the coil which energize the small motor solenoid, and close the armature circuit through the starting resistance. This armature resistance is then gradually cut out, bringing the small motor up to full speed. As the large motor is geared to the press, it also is brought up to a slow speed, though without current in its armature, the full speed of the small motor corresponding to 35 r.p.m. of the large motor. Further motion of the plunger then energizes the large motor through its starting resistance, which is in turn gradually cut out, bringing the large motor up to its maximum speed with full field strength. As the plunger descends still farther, resistance is gradually cut into the shunt field circuit of the large motor. Slow speed operation of both motors is secured by armature resistance, while high speed of the large motor is attained by inserting resistance in the shunt field. The shunt fields of both motors are in the circuit continuously, as long as the main switch is closed, being independent of the action of the solenoid contacts. The dynamic braking thus takes place with full field strength.

The small motor drives the press through a pawl and ratchet. As the large motor attains a speed higher than the maximum speed of the ratchet wheel, which is geared to the small motor, the pawls slip over the teeth on the ratchet wheel until thrown out of contact by centrifugal force. It will be noticed on the diagram that as the large motor takes the load and increases in speed, the starting resistance is cut back into the armature circuit of the small motor, and later the small motor circuit is interrupted by the contacts at the top of the rheostat solenoid, so that the small motor is idle during the normal operation of the press.

The operation of the *Off Coil* serves to energize the coil of the *Rheostat Solenoid* and lift the plunger, making and breaking the various contacts in the reverse order from that of the *On Coil.* When most of the armature resistance has been cut into the circuit of the large motor, the small motor is started again, and brought up to speed, carrying the load again at slow speeds. All resistances

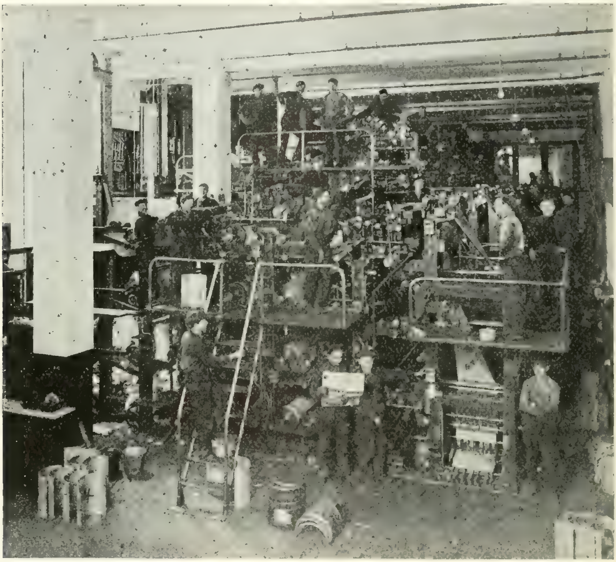


FIG. 6—GENERAL VIEW IN THE PRESS ROOM

There are five large Goss presses in this room. The Kohler control board is on a gallery at the left. The rolls of paper are fed in at the left and come out as finished papers at the right. Several of the stereotype plates which make the impressions are standing in the foreground.

are designed for continuous operation, and as the action of the rheostat can be arrested at any point, it is evident that any desired speed can be maintained indefinitely.

The contacts of the *Safe* button are all in series in the circuit of the *On* button. It is thus impossible to energize the *On* coil when the *Safe* button is pressed, although both the *Off* and the *Stop* buttons can be energized at will.

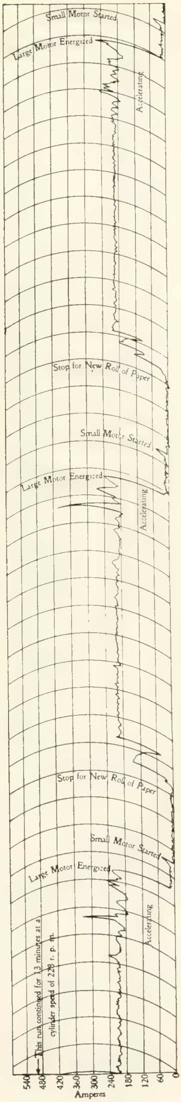


FIG. 7—POWER CURVE OF NORMAL RUN
The motor is accelerated in several steps, and also the speed is reduced in several steps before a stop.

Overload relays are inserted in the armature circuit of both motors, their secondary contacts being in series with the contacts of the *Stop Coil*. The action of any of these coils is to open the control circuit of the *Main Solenoid,* which, in dropping, opens the armature circuit of both motors, and shunts them with a low resistance, bringing the press to a very quick stop.

All coils on the control panel, which remain energized during the operation of the press, are provided with a resistance, which is automatically inserted in the circuit after the magnet operates. This resistance serves to reduce the current to the lowest value which will retain the plunger in position, and prevents heating the coil. Interlocking contacts prevent the main solenoid from closing when the rheostat is not in the starting position, and also close the *Off* coil circuit whenever the *Main Solenoid* is open, returning the rheostat to the starting position. It is thus impossible for the motors to be started or to accelerate in other than the normal manner, and if the press is stopped by the tripping of an overload relay, it can be immediately started again from any of the push button stations, without the necessity of a trip to the control panels.

The operation of the presses is evident from Fig. 6. Each full deck is equipped with two cylinders on the same level, all the cylinders on the press being geared together so as to rotate at exactly the same speed. Each of the stereotype plates covers one-half of the width of the cylinder, so that there are four plates to a cylinder and 44 plates to each five and one-half deck press. For

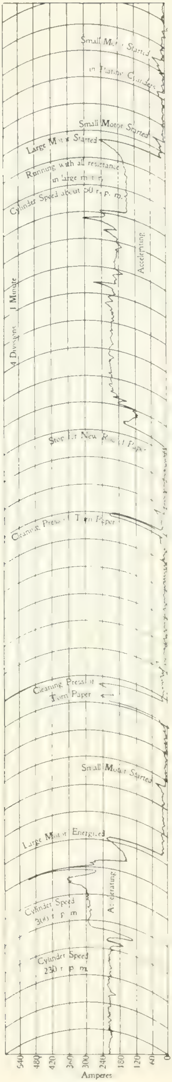


FIG. 8—POWER CURVE TAKEN UNDER SPECIAL CONDITIONS

At the beginning of this curve, reading from right to left, the press was being plated up for a new edition, and the curve shows that the small motor was started several times at short intervals. In the center of the curve, the paper was changed from white to pink on part of the press, and it was necessary to turn the cylinders over slowly while the white paper was run out and the pink threaded in. A little later, the press was run at the maximum possible speed long enough to get a power reading.

a forty-page paper, all of the plates are different. For a twenty-page paper, the plates which are back to back on the cylinders are similar, and two papers are printed at each revolution.

Five rolls of paper are fed into the presses at a time, one roll feeding each deck. Each of the rolls is 38 inches wide and contains 16 500 feet of paper, its weight being about 700 pounds. When running at top speed, the web passes through the presses at the rate of 1 200 feet per minute. The paper passes over one cylinder and under the other on each deck, to receive impressions on both sides, and is pressed firmly against the plates by a blanket covered impression cylinder. The paper from the top roll also passes around the cylinder in the extra half deck, receiving a colored impression for the colored headlines, etc., on the first page.

The ink is supplied by composition rollers, which rotate in contact with the plates on the opposite side from the paper. Any color of ink desired can be supplied to any cylinder, and the paper can be run through as many decks as desired. Thus in the press shown in the foreground, Fig. 6, the paper is regularly run through several decks in succession, receiving a different colored impression from each cylinder. This press is used for the colored supplements of the Sunday edition. On account of the many superimposed impressions, its oper-

ation is necessarily somewhat slower than that of the others in which one color only is used. From the plate cylinders the paper passes to the folder, where the several sheets are arranged in order, pasted in the center, cut apart, folded and counted, every fiftieth paper being thrown out from the folder farther than the others.

Every possible time and labor saving auxiliary has been provided to facilitate the operation of the presses. Extra rolls of paper are kept on racks at the rear of each press so that when a roll from which the press is feeding is exhausted, it can be replaced immediately. Electrically operated paper hoists are used to elevate the rolls from the basement, and place them on the racks. The ink is supplied to the rollers by ink fountains, especially designed to provide a uniform supply, which are in turn fed from a large ink tank in the basement, the ink being raised by compressed air, supplied by a small motor driven compressor, and piped to the desired point on the press.

The power taken by the presses varies both with the speed and the number of decks in operation. The cylinders are so geared together that all must rotate at once. When a deck is idle, however, the ink rolls are lifted, and the drag of the paper is absent. As friction brakes are placed on the end of each roll to keep the paper taut in passing through the press, this makes quite a difference in the power readings.

The curves shown in Figs. 7 and 8 were taken during the regular operation of the press, while printing a 24-page paper at the rate of about 14 000 per hour, using three and one-half decks, with two colors on the first page only. These curves show the character of the load under various conditions, but not at the full capacity of the press. When running at about the same speed, with all decks in operation, printing 20-page papers, the current taken is from 250 to 280 amperes, and when running at full capacity and with a cylinder speed of 300 r.p.m., a reading of 368 amperes was secured.

The readings of the integrating wattmeters on the switchboard indicate a very uniform power consumption. The motors throughout the plant, except the elevators, consume an average of 2 555 kilowatt-hours per week. The lights, including the matrix driers, consume an average of 3 800 kilowatt-hours per week. As tests on the matrix driers indicated a consumption of 1 260 kilowatt-hours, this leaves 2 540 kilowatt-hours used for the lights, or practically the same as for the power.

SECURING FACTORY LOADS FOR CENTRAL STATIONS

LUTHER P. PERRY

ELECTRIC LIGHT and power companies throughout the country are continually endeavoring to increase their motor loads. The more progressive companies have entered into active campaigns to supply all the power required within their franchise limits. This is but the natural function of the central station. As a first requirement in securing this load, power must ordinarily be offered at a price which is less per unit of factory output than that which can be secured by using an isolated plant, and the saving to be secured must be proven conclusively to the prospective power user. The average factory manager is unwilling to concede the numerous advantages of central station service, principally because he is unacquainted with them. He has become attached to his private plant, the product of his own engineering. His accounting system has been arranged to show the cost of manufactured output rather than the cost of the power used. If approached with an invitation to electrify with central station service, he may argue that his engine is used as a reducing valve between the boiler and the exhaust steam heating system; that the labor incident to the production of power would have to be employed anyway, and that certain repairs on the engine, etc., are extraordinary expenses which preferably would not be charged to normal operation of the plant.

To determine definitely the relative cost of isolated plant power and central station power, generalities must be cast aside and the problem attacked in a logical and thorough manner. After an engineer has investigated a private plant, his findings should be presented to the plant management in condensed form, systematically arranged and definitely expressed. The writer has found that reports on private plants may be very effective if developed as follows:—

1—Description of the physical plant, its functions, tests.
2—Analysis of the present yearly cost of power.
3—How to apply central station service.
4—Estimated yearly cost with central station service.
5—Comparison of the cost and the effectiveness of the existing and the proposed systems of motive power.

While including all necessary data, reports must be brief and snappy—logical, not rambling. The superintendent is usually a busy man, and has no time for long drawn out reports. It is sometimes desirable to attract his attention by incorporating in the introductory paragraph a statement of the saving or other results to be effected by the change. He is then more likely to follow the reasoning of the report throughout.

The following is an abstract of a typical power report. In order to reduce it to the space here occupied much of the descriptive matter under the various headings has either been condensed or omitted altogether:—

POWER REPORT OF THE BURTON MOORE CO.

City, State.

Report No. 155. Date, ——.

The Burton Moore Company is engaged in the manufacture of metal stampings and screw machine products. The factory occupies the entire block bounded by Fifth, John, Sixth and Smith streets. Light, heat and belt power are supplied by an isolated steam plant adjacent to main building.

This report gives a comparison between the cost of light, heat and power as at present produced and the cost with electric motor drive using energy purchased from the City Electric Company.

The comparison shows that an annual saving of over $5 000 can be secured, representing a yearly profit of 200 percent on the net investment required to make the change; also that the output can be increased without additional investment for machines, except for the motors, and that the numerous incidental advantages of electric drive will be available.

TABLE OF CONTENTS

(Under this heading an outline index of the report is given for reference purposes. In a type-written report side headings can be used to advantage.)

DESCRIPTION OF THE PRESENT PLANT

Buildings—	Size	Number of Floors.	Volume
Main	60′ x 404′	Basement and 4 floors	1 440 000 cu. ft.
Annex	73′ x 112′	" " 4 "	530 000 cu. ft.
Annealing	48′ x 63′	" " 2 "	(not heated)
Dipping	52′ x 112′	" " 1 "	(not heated)
Office	40′ x 80′	" " 2 "	70 000 cu. ft.
		Total heated contents	2 040 000 cu. ft.

Boilers—Four 200 horse-power Heine water tube boilers installed in 1901, operating at 90 pounds pressure and limited to a pressure of 115 pounds, burning a 1 to 1 mixture of pea coal and Pocahontas coal with a forced draft of 3.5 inches.

Engines—One 36 by 72 inch, 54 r.p.m. Corliss engine built in 1901 is belted to a main jack shaft, to which in turn is belted the machinery on the various floors of the main factory. Part of the exhaust from the engine is used for the vacuum heating system. An indicator card from this engine at about its average load is shown in Fig. 1. One 7 by 8 inch, 200 r.p.m. Ajax engine drives a No. 9 Sterling blower for forced draft under the boilers.

Feed Water—One 3.5 and 5.5 by 5 inch stroke, duplex steam driven feed

pump receives water from the City Water Company at 70 pounds pressure and forces it through the feed water heater to the boilers against a pressure of 90 pounds. All feed water passes through this pump. Allowing ten percent slippage, every complete pump cycle feeds seven pounds of water. For the month ending August 4th, 1910, a counter on the pump registered a total of 4 180 000 pounds. This divided by the 801 400 pounds of coal burned, gives an evaporation of 5.2 pounds of water per pound of coal.

Dipping Room Steam—Three wooden tanks 4 by 4.5 by 5 feet deep are kept full of boiling solution by bleeding in steam. One sawdust box 4 by 4 by 10 feet is kept hot with steam coils. The steam consumption of the above shows a heat expenditure equivalent to the burning of 0.8 tons of coal per day.

Belt Drives—Belts driven from the main jack shaft are numbered from 1 to 8 and drive the following machinery:

No. 1 belt, 26 inches wide and 120 feet long, drives one 100 kw, 125 volt, 600 r.p.m. direct-current generator, nine 250 pound drop hammers, and the machines in the assembling department.

No. 2 belt, etc.

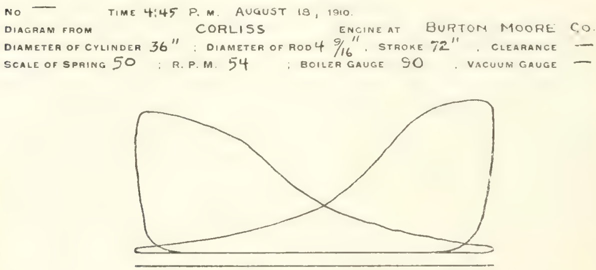


FIG. 1—TYPICAL INDICATOR CARD FROM SIMPLE CORLISS ENGINE

This card has been reduced to two-thirds its original size and indicates a load of 570 horse-power.

Engine Tests—A test in 1903 showed 410 indicated horse power. A test in 1907 showed 460 indicated horse-power.

On April 18th, 1911, engineers made tests in connection with this report every ten minutes, all day. The results appear in the form of a load curve in Fig. 2. The average load was 520 indicated horse-power; the maximum, 615; the minimum during shop hours, 470; and the friction load composed of engine, shafting, and loose pulleys after all employes had left the shop at noon, 260. The lighting generator has an average daily output throughout the year of 174 kilowatt-hours, and a maximum load of 88 kilowatts.

PRESENT COST OF LIGHT, HEAT AND POWER

Plant Costs—The original cost of the boiler and engine plant was as follows:

Power house structure	$ 7 000
Boilers and stack erected	16 000
Engine, foundations and piping	15 000
Jackshaft, heavy belts and generator	7 000
Total	$45 000

Depreciation—The life of this plant is determined not so much by when it becomes physically useless as by when it has become obsolete, at which time it should be replaced by a more effective and economical source of power. An allowance of five percent on the original plant cost will, in 14 years, if compounded, equal the original plant cost. Five percent of \$45 000 is \$2 250.

Interest—It is assumed that the company has set aside each year an allowance to cover depreciation, so that the plant at the present time represents an investment of about \$25 000, upon which interest must be paid at five percent, or \$1 250 yearly.

Taxes and Insurance—2.5 percent of \$25 000 is \$625.

Coal—Actual cost records for the past year give \$15 268.

Labor—Engine and boiler room have been charged \$2 882. Add for the oiler on the inaccessible jack shaft and for the master mechanic, whose attention is frequently required for the upkeep of the heavy transmission equipment, \$600. Total for labor, \$3 482.

Water—Actual cost for the past year, \$1 297.

Oil—Books charge the engine room \$218. To this add for jack shaft oil and grease, and for the blower engine oil, \$468, making a total of \$686.

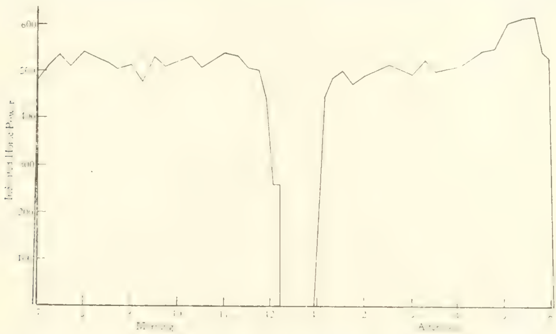


FIG. 2—ENGINE LOAD CURVE, PLOTTED FROM INDICATOR CARDS TAKEN AT 10 MINUTE INTERVALS

Executive Attention—In addition to the labor charges, the production of power makes frequent demands upon the time of the superintendent, while there is a steady demand upon the time of the bookkeepers and purchasing department. The elimination of the private plant may not reduce the salaries of these men, but they will be more valuable in their other duties, and this time should be charged to the production of power. In the present case this amounts to about \$500 per year.

Repairs and Renewals—Cost for the past year, \$600; for the year previous, \$1 500, and average for three years, \$1 000.

Floor Rental—The main belt runs occupy 3 200 square feet of floor area which is worth for manufacturing, at 25 cents per square foot, \$800 per year.

Loss in Production—The drive is so inflexible that trouble with any one of the larger belts, jack shaft, engine or the boilers necessitates the shutting down of the entire plant. These forced shut downs aggregate about ten hours or one day per year and cost in non-productive labor alone, \$500 per year.

Auxiliary Service—The cost of service now purchased from the Electric Company for use when two departments run overtime on repairs and rush orders is \$427 per year.

Sundries—Actual cost recorded on books, \$262.

SUMMARY OF COSTS—STEAM DRIVE

Interest	$ 1 250	Brought forward	$24 858
Depreciation	2 250	Executive attention	500
Taxes and Insurance	625	Repairs and renewals	1 000
Coal	15 268	Floor rental	800
Labor	3 482	Loss in production	500
Water	1 297	Auxiliary service	427
Oil	686	Sundries	262
Part Total	$24 858	Total	$28 347

DESCRIPTION OF MOTOR DRIVE

Installing Motors—Motors can be erected individually by your millwright's force without interfering with the factory output. Existing belts will be gradually disconnected until the engine can be shut down.

LIST OF MOTORS REQUIRED

Size	Speed	Location	Replacing	Driving
25 Hp.	880 r.p.m.	Floor 1	Belt No. 1	Drops
10 Hp.	1 150 r.p.m.	Floor 1	Belt No. 2	Assembly
Etc.				

Total 572 horse-power in motors, cost $4 527.

Net Load on Motors—Average engine load of 520 indicated horse-power less seven percent lost in engine equals 484 brake horse-power at engine flywheel, less 34 horse-power delivered to generator and 52 horse-power to be saved by eliminating heavy shafts and belts, by shutting down department motors when running same short time and by the use of individual motor drive, equals 398 horse-power to be delivered by motors. This means a motor input of 355 kilowatts of electricity, including the motor losses.

Electricity Consumption—Adding 17 kilowatts for lighting to the 355 for power gives 372, the average load. This multiplied by 234 hours per month and by 11.7 working months per year gives a yearly consumption of electricity of 1 018 500 kilowatt-hours.

Lighting System—(Alterations for the new supply and for improving the efficiency of lighting, etc.)

Factory Heating—Exhaust steam will no longer be available and low pressure live steam will be used for heating. The amount of coal required for factory heating and for the dipping department would be computed with reference to the radiation surface. Comparing this factory with others whose coal consumption for heating is known, we would estimate that 510 tons of coal per year will be required.

COST OF LIGHT, HEAT AND POWER WITH CENTRAL STATION SERVICE.

Investment—Boiler plant represents value of $7 187; motors cost $4 527; erecting and wiring motors, $1 400; total, $13 114.

Interest—Five percent of $13 114 is $656.

Depreciation—Five percent will be taken upon half of the original cost of the boiler plant and power house ($11 500), also upon the cost of the motors and wiring ($5 927). Total, $17 427. This is a charge of $871 per year.

Taxes and Insurance—2.5 percent of $13 114 is $328.

Coal—510 tons at $4 equals $2 040 per year.

Labor—In summer the fireman will have little to do, and in winter he can easily handle the boilers for heating. Appropriation, $700.

Renewals—Wholesale elimination of extensive old equipment and re-

duced demands upon the boilers will reduce this item to $200 per year. Following is a list of belts to be discontinued:

No. 1—Main drive belt, etc.

Oil and Waste—Motor oil wells may use 20 gallons per year. Charge for oil, waste, etc., $14.

Removal of Ashes—Reduced in same proportion as coal to $50.

Sundries—With the existing engine drive an abnormal load in one department results either in a slipping belt or broken machinery. With motor drive an abnormal load due to an accident or improper operation of power transmission equipment would cause a fuse to operate allowing the motor to come to rest. Fuses and motor parts are estimated at $50.

Water—With the vacuum return heating system, there will be purchased water to supply leakage only, $85.

Items Eliminated—Motors will be suspended from the ceiling; therefore no floor space is chargeable to distribution of power. The proposed central station service is for 24 hours per day; therefore no auxiliary service charge is necessary, even though one or more departments must work overtime. Judging from a record of the past four years in similar installations there will be no loss in production due to failure of central station power.

Electricity—A yearly consumption of 1 018 500 kw-hrs. would be charged at a rate dependent upon the monthly consumptions, and would for the past year for this plant average 1.8 cents per kw-hr. which would make a yearly bill of $18 333. This especially low rate is possible in this case on account of the favorable load factor, and proximity to the generating station.

The rate schedule follows: (Give rates in detail here.)

SUMMARY OF COSTS—MOTOR DRIVE

Interest	$ 656	Brought forward	$ 4 680
Depreciation	871	Oil and waste	14
Taxes and insurance	328	Repairs and renewals	200
Coal	2 040	Removal of ashes	50
Labor	700	Sundries	50
Water	85	Electricity	18 330
Part Total	$ 4 680	Total	$23 324

CONCLUSION

Present cost of light, heat and power	$28 347
Cost with central station service	23 324
Annual saving with central station service	$ 5 023

The cost of installing the electric drive would not exceed $2 000, were the discarded steam engine, generator, shafting and belts sold and proceeds applied toward the electric equipment.

A profit of 200 percent per year is to be made on the net cash outlay by the use of central station service.

Failure of the Burton Moore Company's present engine drive would cause a tremendous loss in factory output and prestige.

The central station which offers its service has a capacity forty times as great as that of this isolated plant, is equipped with large up-to-date units, is operated as skillfully and with as perfect service as can to-day be produced, and has an enviable reputation for continuity of service.

The best motive power known to man is the electric motor, driven from the modern central station. This power can now be installed in your factory at small expense, and the cost of operating with it is less than your present cost. Respectfully submitted, (Signed)

When such a report has found its way to the hands of the factory management, it immediately becomes the basis for definite

action. A thorough mutual undertsanding is soon reached as to what obstacles, if any, hinder electrification. These barriers will disappear as the sales engineer presents in the proper light the many other attractive features of the proposed service. An increase of output, produced by some change in the layout of the plant or method of manufacture, will secure the favorable attitude of the superintendent toward the whole proposal. The sales engineer cannot know too much about the plant, product or people with whom he is dealing. His view must from the outset be broad and practical. If the factory is mechanically driven and the manager is not acquainted with the advantages of motor drive, it is of paramount importance that a trial installation be made, even if of small scope, and it is a great help if he can be induced to visit a similar plant which is securing power from the central station, or if he can be shown photographs of installations similar to the one proposed. Otherwise he may never really comprehend the benefits to be derived from the service offered.

If for reasons uncontrollable by the central station it is decided not to install motors at once, the matter may be laid upon the table for the time being. Meantime the representative will keep in touch with the situation. A serious breakdown may at any time precipitate immediate action. Enlargements of the factory, demands for more power, impending heavy repairs on boilers, engines or transmissions, removal to a new site, the profitable resale of metered power to tenants, etc., may provide entering wedges for the power salesman. Sometimes the desire to try out a new type of machine, or a few weeks of night running will make possible the initial use of motors; and this in turn may become the nucleus of the complete installation.

In active central station work the accumulation of such reports grows from month to month, all preliminary estimates, data and computations, together with memoranda of important conferences with the prospective customer being filed with the report. A fund of valuable data is thus at hand from which to estimate operating costs of other proposed isolated plants, whose erection would preclude the use of central station service. These reports systematize the efforts, and thereby economize the time of a selling organization, and by their use immediate results may be secured in many cases, while in others contracts may be guaranteed within the near future. They practically always induce the factory manager to consider seriously the adoption of central station energy.

ELECTRICALLY HEATED MATRIX DRIERS

FRANK THORNTON, JR.

ELECTRICALLY heated matrix drying tables, as used in newspaper offices in the preparation of the matrices from which stereotype plates are cast, form one of the most successful examples of the application of electric heating apparatus to industrial work. In newspaper work the time element is of paramount importance. Every minute that can be saved in getting an extra or athletic edition on the streets after the news is received, means a better paper and additional sales. Hence the value of the electric matrix dryers, by means of which from three to five minutes can be saved on each page, over the older steam drying process.

In the preparation of a newspaper page for the press, the first step is to obtain an impression on a mould or matrix of the type composing the form. To accomplish this, a damp, spongy sheet of material about one-sixteenth inch thick is placed over the form and this matrix is pressed onto the type and rapidly dried under a heavy pressure. The drier is composed of a flat bed in which are placed the electrical heating elements which raise the temperature of the drier, form and matrix to a high value. When completely dried, this matrix, carrying a faithful, clear-cut impression of the type, is removed from the drier and placed in the plate casting machine. Here are cast the semi-cylindrical plates which are to be mounted in the presses for the production of the paper.

When it is recognized that one matrix is commonly used for the casting of from four to a dozen plates and may at times be used for as many as 60 plates, it will be seen that it is of the utmost importance to obtain a perfectly uniform and dependable product; and this is made possible by the use of electric driers.

In the past, it has been customary to operate the matrix presses by a hand wheel and screw, a slow and laborious process. The presses were heated to a working temperature by means of steam supplied under pressure from a main boiler plant or from a small, gas-heated steam generator mounted directly beneath the bed of the press. In either case a large amount of heat was liberated into the surrounding air on account of the large radiation surface of the massive construction necessary to withstand the steam pressure. Considerations of safety and economical design limit the pressure of the steam to 80 pounds per square inch, corresponding

to a steam temperature of 320 degrees F. A matrix may be dried by this method in from 4¼ to 12 minutes, depending on the amount of open space in the forms and the quality of the absorbing pads.

By substituting compressed air for the hand wheel, a quick, certain pressure is obtained, which can be definitely fixed at any desired value and which remains constant during the whole drying operation. Control of the pressure is obtained by means of an easily operated air-valve. By the use of electric heaters a higher temperature can be secured than with steam, the melting point of

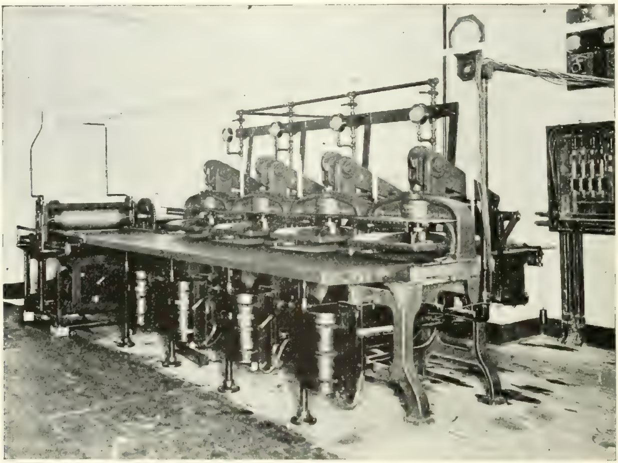


FIG. 1—ELECTRICALLY HEATED MATRIX DRIERS
Installed in the plant of the Pittsburgh Press.

the type metal being the only temperature limit, and thus the drying process can be completed in a much shorter time than is possible with steam. Perfect matrices are obtained with the electrically heated presses in from 1¼ to 3 minutes.

Exhaustive tests have been made on the electrically heated matrix driers installed by the *"Pittsburg Press"* with the view of determining the energy required. There are four presses in the set, as shown in Fig. 1, each press being independently controlled and taking a minimum of 1.1 kilowatt and a maximum of 13.5 kilowatts. Each press is equipped with a thermostat which operates a circuit-

breaker and which is set to limit the maximum temperature on the press to approximately 380 degrees F. and the minimum to 350 degrees.

The heater bed consists of a heavy iron casting, cored to include six longitudinal holes which are accurately machined to a rectangular section. These holes form the casting into a series of box girders, which impart the highest degree of rigidity to the bed, with the least amount of metal, thus allowing the application of the heaviest pressure which can be applied without damaging the type. In each opening is placed a heating unit, consisting of a soapstone core which is grooved from end to end, to contain the heating element.

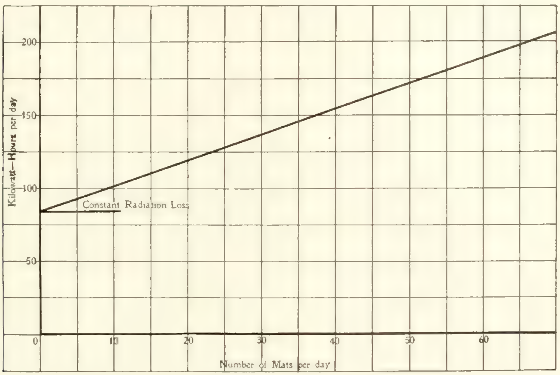


FIG. 2—POWER CONSUMPTION OF BANK OF FOUR MATRIX DRIERS

The element is sealed in place with a special cement, mixed with soapstone dust, which serves at once to hold the conductor in place, to insulate it electrically, and to conduct the heat. The unit fits snugly into the holes in the heater bed, and is thoroughly packed around with the soapstone dust to aid in conducting the heat. The soapstone acts also as a storage reservoir for the heat, thus aiding to reduce the temperature fluctuations in the surface of the bed. The input to each press may be regulated by means of a separate controller, consisting of three double-pole, double-throw knife switches, each of which controls an independent heater circuit distributed over the entire surface of the press bed. Each circuit is divided into two equal sections to give series-parallel control, the minimum

consumption of each circuit being 1.1 kilowatt, the maximum 4.5 kilowatts.

The results of the tests are as follows:—

1—The minimum time required for the production of a satisfactory matrix was one minute, 15 seconds.

2—The total number of kilowatt-hours required in an eight-hour day for varying numbers of matrices is shown in Fig. 2, a working temperature being maintained throughout the entire day.

3—The total amount of energy required for a period of seven days to produce 270 matrices for the various editions of the paper, including one Sunday morning edition, was 1 050 kilowatt-hours.

Similar tests on an installation of four gas-heated steam tables of approximately the same output give the following results:—

1—The minimum time to produce a matrix was four minutes, 15 seconds.

2—The natural gas consumption for a period of seven days was 12 300 cubic feet.

Aside from the saving in time, it should be noted that the average amount of heat liberated per day by the electric presses is approximately 500 000 B.t.u., as compared with 1 750 000 B.t.u. for the same time by the gas-heated tables. The lesser amount of heat results, of course, in a very appreciable reduction in the temperature of the work room.

With gas costing $1.00 per thousand cubic feet and electricity at 1.25 cents per kilowatt-hour, the power costs would be approximately equal. In an application of this kind, however, the saving of time and the simplicity of control, as well as the general operating convenience, are of such importance as to entirely overshadow considerations of operating costs.

RELATION OF LOAD TO STATION EQUIPMENT*

F. D. NEWBURY

THE capacity of a given generator will vary inversely with the power-factor, that is, the lower the power-factor the larger the generator required. With a given energy load the kilo-volt-ampere capacity of a generator must be greater with low power-factor, not only on account of the larger k.v.a. load, but on account of the larger field current required to maintain normal voltage. It is of prime importance to have plenty of margin in excitation voltage to enable the generator to maintain normal voltage under unusual load conditions. To insure this requires a knowledge of the probable power-factor under which the generator will operate, since reduction in power-factor involves such a large increase in exciting current.

DETERMINATION OF POWER-FACTOR

In laying out a central station it is impossible to predict exactly the power-factor that will result when the entire system is in operation. It is possible, however, to approximate very closely the operating power-factor from experience with existing plants offering similar service. The following general statements regarding probable power-factors have been abundantly proven by experience:—

1—Operating power-factors above 95 percent will be obtained only when practically all of the load is synchronous motors or rotary converters which may be operated at approximately unity power-factor; that is, without any wattless component. Even with this character of load, the generators should be capable of operating satisfactorily at 95 percent power-factor to provide for unforeseen contingencies.

2—Power-factors of 90 to 95 percent can be safely predicted only when the load is entirely incandescent lighting or heating, or if a large non-inductive load, such as synchronous motors or rotary converters, is used with a smaller proportion of inductive power load.

3—For the average central-station load, consisting of lighting and power, a power-factor of 80 percent should be assumed.

4—A power-factor of 70 percent should be assumed for a plant having a large proportion of induction motors, arc lighting, electric furnaces or electric welding load.

In the above statements, the figures given are conservative from the standpoint of the generating equipment. The maximum gen-

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*Condensed from a paper read at the annual Convention of the National Electric Light Association, held at New York City, May 29-June 2, 1911.

erator rating in kilowatts should be equivalent to the maximum engine rating in kilowatts. Since the size of the generator is determined from the kilovolt-ampere rating, rather than the kilowatt rating, the size of the generator for a given engine will depend on the operating power-factor.

As an example of the proper method of comparison, assume a generator having a normal rating of 1 000 k.v.a. and a maximum continuous rating of 1 250 k.v.a. at 80 percent power-factor. This is 1 000 kw, and the *maximum* continuous engine rating should be proportioned to 1 000 kw. To select the prime mover of a generator on the basis of normal 100 percent power-factor generally results in an engine or water wheel too large for the generator.

When the question is one of adding a new load to an existing station, the power-factor of the new load can be approximated from the following:—

Incandescent Lighting Load with Small Lowering Transformers—Approximate power-factor 90-95 percent.

Enclosed Arc Lamp Load with Constant Current Transformers—Power-factor 60-75 percent, depending on whether the transformers are supplying their rated number of lamps.

Metallic Arc Lamp Load with Rectifiers—Power-factor 55—70 percent depending upon whether the rectifiers are supplying their rated number of lamps.

Induction Motor Load; Squirrel Cage Rotor, Single-Phase, 0.05 to One Hp—Power-factor 55-75 percent, average 68 percent at rated load; Squirrel Cage Rotor, Single-Phase, One to Ten Hp—Power-factor 75 to 86 percent, average 82 percent at rated load; Squirrel Cage, Polyphase, One to Ten Hp—Power-factor 75 to 91 percent, average 85 percent at rated load; Squirrel Cage, Polyphase, 10 to 50 Hp—Power-factor 85-92 percent, average 89 percent at rated load; Phase-wound Rotors, Polyphase, 5-20 Hp—Power-factor 80 to 89 percent, average 86 percent at rated load; Phase-wound Rotors, Polyphase, 20 to 100 Hp—82 to 90 percent, average 87 percent at rated load.

Rotary Converter Load, (1) Compound Wound—The Power-factor can be adjusted at practically 100 percent at full load, at light loads it will be lagging and at overloads slightly leading; (2) Shunt Wound—The Power-factor can be adjusted to any desired value and will be fairly constant at all loads with a given field rheostat adjustment.

Small Heating Apparatus—Same characteristics as incandescent lighting load.

Arc Furnaces—Power-factor 80 to 90 percent.

Induction Furnaces—Power-factor 60 to 70 percent.

Electric Welding Transformers—Power-factor 50 to 70 percent.

Synchronous Motors—Power-factor can be adjusted between practically zero leading and zero lagging power-factor.

From the above it may be seen that the only kind of load which

affords any control over power-factor is that furnished by synchronous motors. This fact has led to an increasing use of synchronous motors by central stations."

In cases of low power-factor, where no mechanical or direct-current load is required, synchronous motors have been installed running without energy load. It is, however, more economical to utilize a synchronous motor for energy load as well as for wattless magnetizing current, since the required capacity of the motor is determined by the geometrical sum of the components (which are at right angles) and not by the direct arithmetical sum.

Numerous methods for determining the proper size of synchronous motor to effect a certain improvement in power-factor have been proposed, but they are all based on these four propositions:—

1—The actual load on the station can be divided into two right-angle components.

2—The total energy component of the station load is equal to the sum of all the individual energy components in the system.

3—The total wattless component of the station load is equal to the sum of all the individual wattless components in the system, proper attention being given to the kind of wattless component existing. The magnetizing, or the leading, components should be subtracted from the demagnetizing, or lagging, components. In other words, they neutralize each other, and an ideal condition is obtained with regard to power-factor when the magnetizing components in the system are sufficient to completely neutralize the demagnetizing components.

4—Since the power-factor is the ratio of the energy component to the total load, the energy component can be determined directly by multiplying the total load in k.v.a. by the power-factor. The wattless component can be determined from the relation existing between the three sides of a right-angle triangle (when two sides are known).

In general it takes a large increase in synchronous motor capacity to raise the power-factor above 90 percent, and ordinarily it will not be found worth while to raise a station power-factor above 90 percent since the investment necessary is seldom warranted by the improvement in operation.

INSTANTANEOUS CURRENT DEMAND

From the standpoint of the station equipment, the instantaneous current demand is of importance when the size of the demand becomes a large proportion of the station capacity or of the load on a given feeder. Loads resulting in wide fluctuations in current demand may be satisfactorily supplied when there is an

additional steady load on the same feeders which is not sensitive to voltage fluctuations. A certain power company supplied a large constant direct-current motor load and a small variable elevator load from the same motor-generator set. The constant motor load was gradually decreased and the elevator load increased until the elevator service became unsatisfactory on account of voltage fluctuations. The service was changed from one eminently satisfactory to one very unsatisfactory simply by changing the proportions of constant and variable load on the same motor-generator set.

Another common source of trouble from large momentary currents is due to the starting of synchronous and induction motors and rotary converters. An idea of the starting performance of these various machines is given in Table I.

TABLE I—STARTING PERFORMANCE OF VARIOUS MACHINES

Machine.	Torque while Starting Times Full-Load Torque.	Starting Current in Line Times Full-Load Current.
Single-Phase Induction Motors, with Clutch, Split-Phase Starter	1 to 1¼	4½ to 6
Single-Phase Induction Motors, without Clutch, Split Phase Starter	2	3½ to 4½
Polyphase Induction Motors, Cage-Wound Type	1	3½ to 4
Auto-Transformer Starter	2	7 to 8
Polyphase Induction Motors, Wound-Rotor Type	1	1¼
Step-by-step Resistance Starter	2	2½
Synchronous Motors	0.3 to 0.5	½ to 2½
Auto-Transformer Starter	0.7 to 1	4 to 8
Rotary Converter	0.2	1½
Auto-Transformer Starter	(Sufficient to start itself)	

In the above table, the smaller torque figures given for synchronous motors cover the requirements of motor-generator sets and air compressors and pumps when the apparatus can be started without load. The larger torque figures refer to motors for driving pumps and fans, which must be started under practically full-load conditions. The wide variation in the starting current comes from differences in construction of the motor, or differences in the proportions of the motor, since, by increasing the size and cost of synchronous motors, the starting performance can be materially improved.

SIXTY-CYCLE ROTARY CONVERTERS

Many central stations have a combined lighting and railway load, the lighting and general power being supplied directly from 60 cycle generators and the railway load by 60 cycle rotary con-

verters or motor-generator sets. The question as to whether rotary converters or motor-generator sets should be used cannot be given a definite answer without relation to all the operating conditions, but the following characteristics of the two classes of machines will be of assistance in making a correct decision:—

First Cost, Efficiency and *Floor Space* will be in favor of the rotary converter, even when the motor-generator set can be wound for line voltage, and still more so when transformers have to be used with the motor-generator set, which is the case whenever the line voltage is above 13 200 volts.

Voltage Control is in favor of the motor-generator set, but this is of minor importance for railway work. The compound-wound rotary converter, practically in universal use for railway systems, meets the requirements.

Power-Factor Control is in favor of the motor-generator set, since the synchronous motor can be utilized to any extent for power-factor correction. At the same time the beneficial effect on power-factor of adding a large non-inductive load, such as rotary converters, should not be lost sight of.

From the foregoing it is evident that for the great majority of cases the rotary converter can be used to greater advantage than the motor-generator set. In the past the 60 cycle rotary converter has been criticised on account of its sensitiveness in operation and the consequent necessity for skillful operators. During the past two years this class of machines has been materially improved in this respect, and 60 cycle converters are now built which are thoroughly satisfactory with the same grade of attendance required by any rotating electrical apparatus. This improvement has been secured by using fewer poles, permitting a wide range in brush position without sparking and flashing, and by higher commutator peripheral speed, permitting more commutator bars per pole. The use of fewer poles has, with the constant frequency, resulted in higher speeds.

CONTINUITY OF POWER SERVICE

R. P. JACKSON

[This is the ninth and concluding article of the series on the general subject of continuity of service in transmission systems.]

IN THE generation, transmission and distribution of power there are two essential elements that effect the marketability of the product. The first is the cost of the delivered power and the second, the reliability of the service. The following paper is confined to the latter subject and an attempt has been made to describe the more common causes of service interruption and to indicate the most successful methods at present available for preventing such interruption.. It should be understood, of course, that the art of handling power electrically is progressing and that some of the statements made herein are necessarily comparative; their accuracy later may depend on the success and trend of development now in progress.

The following is a list of the more common elements contributory to interruption of service:—

External Causes
- Lightning storms
- Sleet and wind storms, floods, etc.
- Ice—Floating, anchor, etc.

Internal Causes
- Inadequate station equipment such as relays, circuit breakers, etc., or inflexibility of switching arrangements
- Inadequate line construction or insufficient number of lines
- Material defective in design or quality
- Deterioration of equipment (such as decay or burning) in the natural course of operation.
- Abnormal surges, resonance, etc., due to circuit constants

Personnel of Operating Force
- Inadequate organization to care for abnormal situations
- Lack of resourcefulness of operating attendants

Any of the above factors may work together to cause interruptions of service and it is not uncommon for one to be the origin of trouble and another to prolong the interruption or permit conditions to develope to a degree much worse than the exciting cause would warrant.

EXTERNAL CAUSES

LIGHTNING

Lightning storms form far the larger part of the local sources of trouble on most power systems and the operating company is fortunate indeed if so located as to be immune. Lightning trouble is manifested in two ways, the oldest and most familiar being the injuring of generating or transforming apparatus in the station; but the most serious to many high voltage transmission companies at the present time is the damaging of the transmission line by the break-down and destruction of one or more insulators.

The puncturing of insulation of generators, transformers, motors, etc., between turns or to ground is a familiar trouble and the common remedies are choke coils, lightning arresters, and more and better insulation. The choke coil has no effect in relieving over-voltage but acts to retard and reflect, and thereby suppress, high frequency waves—or more properly, such waves as have an extremely steep front. Unless the insulation of the power apparatus can be made specially strong between turns it is very desirable if not essential to protect it by means of choke coils.

The lightning arrester is essentially a vent or relief valve such as will permit charges of excessive potential to escape from the working conductors at a predetermined point where damage to other apparatus will not result. If possible, it is desirable that the arrester shall perform this function without at the same time permitting the escape of power current or causing other disturbance to the circuit. The ease with which a device can be made to accomplish this purpose depends somewhat on the operating voltage and still more on the amount of power behind the circuit. Arresters whose design is based on the use of non-arcing metal have been employed for a number of years with considerable success. This non-arcing quality of the metal is, however, of limited power and depends on the amount of heat developed at the points where the spark passes. For this reason repeated discharges in very rapid succession or discharges of unusual volume may cause the vaporization of so much metal as to permit welding and consequent distruction of the arresters.

The more recent arresters of the electrolytic or aluminum type, which depend upon an electric valve action of a film which in certain electrolytes will form on aluminum, have proved much more stable under repeated discharges and are less subject to damage

when used on heavy power circuits. While somewhat expensive, the electrolytic type of arrester can be made to perform its proper function most satisfactorily and approaches more nearly the ideal lightning arrester.

The attention required by the aluminum electrolytic arrester has given rise to experiments with plain horn gaps, with and without resistance, to limit the current at time of discharge. The horn gap without resistance can hardly be considered a commercial arrester, as with it there can be no pretense of limiting the power current which may follow a discharge across the gap. When a resistance is used in series with the horn gap the stability of the combination depends somewhat upon the nature and ruggedness of the resistance. The advisability of using such an arrester, under given conditions, depends on the strength of the apparatus to be protected and on the nature of the circuit; that is, whether the momentary escape of a considerable amount of power will disturb other apparatus such as synchronous motors, water wheel governors, etc. It may be stated in general that generators feeding directly to the line should be provided with the *very best protective* devices available while, for high voltage oil transformers, some simple and less expensive device may be satisfactory on account of the more rugged nature of this kind of power apparatus. *

Interruption of high voltage transmission service by lightning is more commonly caused by damage to the transmission line itself than to the station equipment. The common form of such trouble is the breaking of line insulators thereby grounding or short-circuiting the line and sometimes burning the conductors in two as a result of the arc formed. This kind of trouble is more common on steel tower lines or wood pole lines on which the pins are metal and grounded by means of wires carried down the pole.

Insulator breakage of this kind may occasionally be caused by direct strokes of lightning or by the small branch or filament strokes sometimes observed in forked lightning. In general, however, the stress probably originates from the presence of a charged cloud overhead. If such a charge exists for an appreciable time over a transmission line a charge of opposite sign will of course appear on the surface of the earth beneath and the static stress will be such

*This subject has been discussed in the present series as follows: March, 1910, p. 238; April, 1910, pp. 313-315; August, 1910, pp. 612-616; September, 1910, p. 725.

as to make these two charges attempt to reach each other. As a result the charge on the ground will creep over the insulators and locally charge the line wires with the same sign as that on the earth. This charge may exist "bound" or "floating" on the line in the vicinity of the cloud and not interfere in any way with the passage of the normal load current. When a lightning flash occurs, however, and the charge in the cloud is carried to ground, the local charge on the line wires becomes free and its potential is suddenly manifest. While the charge is free to flow in either direction along the line, as a matter of fact the reactance or electrical inertia of the line is such that, if the potential of this charge is great enough, it promptly breaks over or through the nearest insulator and passes off in a small spark. In fact the line may be grounded at no great distance away and yet the charge will not travel along the line to the ground but to a very large extent will pass off locally. An additional reason for the failure of the charge to travel is disclosed by Dr. Steinmetz.* It appears that for an exceedingly high frequency or a very steep wave front, the effective resistance of a conductor becomes many times its true resistance at normal frequency, due not only to so-called "skin-effect," but to the radiation of energy in the form of magnetic waves. The net result, at least, is analogous to the bursting of a pipe in which a charge of dynamite is exploded. Even though the pipe is open at both ends it will burst. Such a result will not be obtained if the explosive is such that the pressure develops more slowly, but instead the gases will escape each way in the pipe.

The secondary, but really serious, result of the spark over the insulator is that power current follows, producing a vicious arc which destroys the insulator and perhaps burns the transmission cable to such a degree as to permit it to break. It occasionally happens that the insulator is punctured by the initial spark, but in the great majority of cases the sequence seems to be as above indicated. When the structure supporting the insulators is of wood its resistance is usually so high as to prevent any power arc and consequently the initial spark passes off harmlessly if the insulators are of proper design, that is, so constructed as to flash over the surface at a lower voltage than that which will puncture them.

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*See chapters 8 and 9, sec. III, of Steinmetz's *Transient Electric Phenomena*, pp. 387-413.

The difficulty with an all-wood construction, however, is that direct strokes of lightning will shatter the poles and will leave the line unsupported, and when the insulator pins are of wood they are liable to burn from leakage over the insulators if the voltage is 30 000 or over. If wood poles are used the best results seem to be obtained when the pins are of metal and a metal wire is run up the pole to the top to prevent lightning from shattering it. If there is a considerable length of wood between the pins and the ground wire, power current is less likely to follow a spark over an insulator and neither do the pins burn, being of metal. Cross-arms may burn occasionally but this seems to be rather rare unless a conductor becomes detached from the insulator and lies on the cross-arm.

When an all-steel structure is used, a flash over an insulator is very likely to result in an arc which will wreck the insulator. One remedy is to carry the grounded metal structure up around the insulator in such a way that the arc to it will be drawn away from the insulator until the proper circuit breakers can open or disconnect the circuit. The insulator being intact, power can be put back on the line and nothing more than a momentary interruption may result. While such interruptions may not be desirable they may be decidedly the less of two evils, the other of which might be an interruption of several hours. Considerable synchronous machinery, with an extensive low-tension distributing system, may make a momentary shut down of the transmission line very serious, but on the other hand if the load is such as to be readily picked up again the momentary cutting off of power may be of trifling consequence. For this reason the above expedient would be received favorably by some operating companies but not by others. *

The location of the transmission line itself may affect this matter of insulator damage by lightning. A specific case may be cited as an illustration. A certain steel tower line ran for a number of miles over high mountainous and exposed country and then dropped down into a valley and continued for a similar distance just beneath a high wooded bluff. Many insulators were broken on the exposed section of the line and none whatever on the section below the bluff.

Recently an expedient has been tried with promise of success, the purpose of which is to suppress the arc over a line insulator in

Mr. L. C. Nicholson has described the above method of protecting transmission lines in his paper of March, 1910, before the *A. I. E. E.

such a short time that no damage will result to the insulator. This is accomplished by temporarily grounding at the power house the phase having the arcing insulator. This of course short-circuits the arc over the insulator so that it is immediately extinguished. The ground at the power house is then at once cleared by means of an oil switch or fuse. This method is reported to operate successfully on either a grounded or ungrounded neutral circuit, providing there is but one phase in trouble. It has not so far been reported as operative in case of flash-over of two insulators occuring simultaneously. On account of the comparatively small expense of the apparatus this expedient may prove to be a helpful one for preventing insulator breakage and service interruption. *

Overhead Grounded Conductor—Operating men who have carefully tried the overhead grounded conductor seem to be in accord in the statement that it is of material assistance in minimizing insulator breakage by lightning and also reducing station trouble from the same cause. It is essential, however, that the wire or cable used for this purpose be sufficiently strong to prevent breakage and well enough protected to prevent rust. Otherwise it may cause more trouble than it will cure. The more frequently this wire is grounded the better, though it is not important that each individual ground be of very low resistance. The object in frequent grounds is to eliminate as far as possible the local impedance of the conductor so that the charge on it may change from one sign to the other very quickly by way of the ground. The use of barbed fence wire is not to be recommended because it is likely to deteriorate rapidly and cause trouble by breaking. Double galvanized steel cable of size suitable for the spans has proved satisfactory. Two or three such conductors spaced over the line are much better than one, and it is the opinion of some engineers that if as many as five wires were placed so as to form a half cylinder over the transmission line there would be practically no trouble from lightning. In addition the grounded conductor acts quietly and entirely without disturbance to the circuit, being essentially a shielding and damping device.

The Suspension Insulator—An insulator of the suspension type has been used to some extent on lines of 60 000 to 110 000 volts

*Papers by Mr. E. E. Creighton, Messrs. Marvin and Burkholder, and discussion by Mr. L. C. Nicholson, *A. I. E. E.*, February, 1911, describe the details of the apparatus and its operative characteristics.

and higher with very good success. The distribution of the stress over several pieces of porcelain which are separated some distance with metal between them appears to operate to prevent all the sections of porcelain being broken at once. Cases are on record where three sections out of the five in series have been destroyed and the line continued to operate on the other two. The suspension insulator, giving a flexible support for the line wires, should relieve them of mechanical stresses incident to vibration. Another incidental advantage of this type of insulator is that an excellent location is provided for an overhead grounded conductor directly above each wire. For this reason suspension insulators should find application on lower voltage lines now commonly carried on pin insulators.

SLEET, WIND STORMS, FLOODS

Sleet is essentially a local trouble (as some territories are reported to be entirely free from it while others suffer repeatedly). The frequency of visitations of sleet storms is not nearly so great as that of lightning storms. The amount of ice that can form on a small wire is astonishing. Sleet may cover and short-circuit insulators but commonly its effect is to so weight the conductors as to either cause them to break or to damage their supporting structures. This is not so common an occurrence with power line conductors as with the telephone wires which are so essential to the operation of the power line. Another annoying feature is that if the power line is damaged by sleet the telephone lines are almost certain to be affected and the difficulty of making repairs and getting power on the line is thus much increased. Sleet was reported from the Great Lakes region on a one-half inch cable causing ice three inches in diameter. It is doubtful of any company could protect itself entirely against abnormal conditions such as this; however sleet storms are usually of limited extent, at least in their most severe form, and two or more lines separated a considerable distance are not likely to be affected at the same time.

Wind of high velocity is known to produce two troubles. Lines and line structures in which the factor of safety is not great, may be damaged or broken down entirely. Wood poles supporting heavy conductors are more likely to suffer in this respect, but steel towers located on soft ground which has not had time to settle about the tower footings have been overturned bodily. Cases have been known where ground which was solid and apparently entirely safe

when dry became treacherous when wet. The obvious remedy is a proper factor of safety of the structure and supports and a careful investigation of suspicious soil on which structures are to stand.

In some parts of the country, particularly mountainous districts, the blowing of a dry wind across the line causes it to become charged to a potential so great as to break over insulators or lightning arrester gaps. While the ordinary lightning arresters should permit the periodic discharge of these accumulations, the better and more satisfactory method consists in grounding a neutral point of the transmission system. Even though this ground be through a high resistance it will entirely free the line from slow accumulations of charge.

Floods may be disastrous in the case of hydroelectric stations by carrying away dams and destroying power houses. Interruptions are caused, however, in some forms of power houses by temporary raising of the water level from various causes. Floods are essentially local and the remedy is necessarily special for each location.

FLOATING ICE—ANCHOR ICE

In the extreme North ice is often a serious trouble to companies depending on water power. Long intake canals in which the water moves slowly are said to favor the formation of troublesome ice, while if the water can be drawn from the bottom of a deep and quiet pool, the ice on the surface of which, if loose, passes off over the wier, the least trouble will be experienced. "Floating" ice consists of loose blocks which may accumulate and block channels and shut off water. So-called "anchor" or "frazil" ice is in the form of small crystals or needles distributed through the water and having a tendency to adhere to any cold surface and accumulate into solid masses. Grates, penstocks and wheels may be blocked by such ice and it is extremely difficult to get rid of. Keeping the surfaces to which it may adhere slightly warmer than the water has been found to be the best way to prevent this ice clinging and forming blocks. If it can be kept from adhering to surfaces these crystals will pass through the wheels and do no harm.

INTERNAL CAUSES

STATION APPARATUS

Station equipment may sometimes fail due to accident or inherent weakness, or it may be overloaded of necessity or through

lack of knowledge of its limitations. It often happens that some features of the station equipment, while not causing interruptions of themselves, will permit or prolong them by failure to localize troubles of some other origin. A study of the power house and switchboard practice is necessary to comprehend all the features of this question and a few rules only can be suggested.

1—No essential piece of apparatus should be so constructed and placed that it cannot be cut out for repairs without an interruption of service.

2—An effort should be made, by means of relays, to permit one of two or more parallel lines to trip out where defective without interrupting power on the other lines.

3—Provision should be made to permit the station attendants to know as quickly and conveniently as possible, just what is going on in different parts of his station and on such parts of the line or system as concern him.

4—Equipment should be so arranged as to enable the station men to cut out defective apparatus on lines and readjust themselves to abnormal conditions quickly and without danger to themselves or others.

5—The station wiring and the placing of apparatus should be such that trouble in one place will be least likely to spread to adjacent apparatus.

6—In so far as possible, circuit interrupting apparatus should not be so placed as to be compelled to open overloads or short-circuits of much greater capacity than that for which they were intended when designed.

THE LINE

Line construction may be of a type entirely satisfactory for power stations of moderate capacity but inadequate when higher voltages or, especially, greater power is carried. Much that might be said under this head is already covered in previous pages of the present series in regard to types of construction which will best resist lightning. It is almost needless to say that, so far as expense will permit, the line structures should be strong enough mechanically to withstand wind, sleet and similar stresses and such abnormal stresses as appear when one or more conductors become broken.

It is found that if an arc forms between conductors it almost invariably occurs at the insulators as a result of a flash-over. Moreover, such an arc with certain volume of current and size of conductor will burn the conductor in two—sometimes very quickly. Just what combination of current in the arc, size of conductor,

material of the conductor and stress thereon will cause it to burn in two is difficult to determine and there is not much data available. In general the conductors of high voltage lines should be protected by a serving wrapping or other shield near the insulators to prevent the actual conductor from being burned.

The location of line trouble quickly is of course vital to speedy repairing of the damage. Such location is, however, difficult, especially on long lines traversing rough country. This is particularly true if the search has to be made at night. A road or pathway along the line greatly facilitates the inspection of the line and a search-light will enable fractured insulators to be detected at night particularly if they have a colored glaze. An automobile with a search-light attached to the dash board has been found by the Niagara, Lockport & Ontario Power Co. to be a great convenience for patrolling the line. It has been found also that the breaking up of a line into sections by means of disconnecting switches will often greatly facilitate the location and repair of damage. If power is available at both ends two crews may begin testing out and repairing such sections as they can handle conveniently. Having one section repaired and tested, a crew proceeds to the next section with assurance that some damage has not been left unrepaired miles behind them.

Where steel tower or grounded pin construction is used it is often possible to locate a defect on a line by electrical tests analogous to those used in finding faults in telephone cables. Mr. L. C. Nicholson has described a method * of this kind which consists essentially in measuring the impedance from the power station to a fault (commonly a broken insulator) over two paths. One of these paths is that made by the affected wire directly from the power station to the fault. The other is made up of the other conductors to the distant station and from there back to the fault on the affected wire. A high alternating voltage is used and the impedance values are measured by the current in the respective branches of the circuit. Very good results have been obtained by Mr. Nicholson with this method on a line having grounded insulator pins.

While not coming exactly under the head of line construction it may be said that at least two lines must supply each important load if any great guarantee against the cutting off of power is to

*"The Location of Broken Insulators and other Transmission Line Troubles," *A. I. E. E.*, June, 1907.

be made. It is a distinct advantage, if the power supply and the load are a great distance apart, to have them connected by lines traversing different parts of the country in order that a storm may not affect both, at least not simultaneously. Furthermore if a steam auxiliary to water power is provided it should be near the load, if possible, so that a failure of the transmission line may not interfere with both sources of power. The writer found one case where the steam auxiliary was located in the water power station, with the result that if the transmission line failed the steam power was in just as helpless a position as the water power.

MATERIAL

Most material which might prove defective can be eliminated by suitable tests but there are some kinds for which experience covering a considerable period of time is required in order to enable one to determine their value. Under this class may be placed protective coatings such as paint or galvanizing, treatment for wood used for insulator pins, etc. Most information of this kind is now available in some form and no great difficulty should be encountered in getting satisfactory material.

UNDUE DETERIORATION

Deterioration of equipment at an abnormal rate may occur at times and cause unexpected failure of apparatus. Overloading and consequent overheating of insulation is a fruitful source of trouble. Adequate capacity of apparatus for peak loads is desirable and an accurate knowledge of the safe overload capacity of apparatus *in the place where it is installed* is essential to avoid trouble from this source. When special connections of transformers are used or transformers of possibly different characteristics are run in parallel a clear understanding should be obtained as to how the load will divide between the different units. In general the apparatus furnished by the manufacturing companies is well able to meet the guarantees; but when so placed as not to receive proper ventilation or so connected as to be overloaded and overheated without the knowledge or intent of the operator it sometimes fails unexpectedly from no fault of its own.

Wood insulator pins for 30 000 volts and upward are often burned by the leakage current over the insulators or by the capacity current of the insulator acting as a condenser. Such burning is of an irregular, honey-combed nature and not always readily visible. It may permit the insulator to drop from its support and ground the

line. Such burning seems to be worse the higher the voltage and the greater the voltage stress on the insulator. Boiling the pins in creosote oil or in paraffin is considered the best treatment and by some engineers is considered satisfactory up to 50 to 60 kilovolts, but other engineers prefer that all pins for use on voltages above 30 000 be of metal.

SURGES AND RESONANCE

Surges, resonance, etc., are at times the cause of insulation failure, consequent interruption, and perhaps damage to apparatus. It is difficult to define the conditions which will or will not produce such trouble. Arcing grounds are sometimes a cause of surges or high frequency disturbances travelling back and forth over the line. A short-circuit of great capacity very suddenly opened may cause an inductive rise of voltage at the point where the opening occurs. The closing of a switch between a live circuit and the high potential windings of an unexcited transformer causes severe stress between turns of the transformer windings. It is preferable, if possible, to connect a transformer or bank of transformers on the low side first so that the windings are at about full potential before the circuit is closed on the high side. This is not always possible, as in the case of an isolated sub-station with but one set of transformers; if the only power such a station can receive must come from the transmission line, it is obvious that the switching must be done on the high side. Modern transformers, with extra insulation on the end turns, are not likely to give trouble from this source but if there is opportunity it is still preferable to minimize the stress as much as possible by doing the switching on the low side.

Under normal conditions a transmission line operates in a state of static equilibrium relative to ground potential. That is, the positive static charges on part of the generator or transformer system are just equal to the negative static charges on the remaining portions of the system. In the event, however, of breakdown of the insulation between the high and low-tension transformer windings, the low-tension system in circuit with the transformers may be raised to a static potential so far above its normal potential as to cause trouble in connection with connected apparatus or serious life and fire risk. A similar condition of abnormal static potential on the low-tension side of the system is caused by an accidental ground on one side of the high-tension circuit, as the result of con-

denser action between high and low-tension windings of the transformers considered as condenser plates separated by a dielectric consisting of the insulation between them.* Such a condition is prevented by connecting a neutral point of the low-tension circuit to ground through a small resistance.

Cables which form a part of a transmission system are especially susceptible to trouble from surges involving relatively larger amounts of energy than would be possible in overhead circuits of otherwise similar characteristics, due to their large electrostatic capacity between conductors and from these to ground (sheath), and the lower inductance resulting from the closer proximity of the conductors. Hence, the additional importance of maintaining static equilibrium of the transmission system by suitable grounding at neutral points as well as the importance of protecting the cables themselves by providing a means of escape for such static charges as may appear therein, in the form of suitable discharge gaps at the cable-heads, so arranged as to give a moderately free discharge path to ground. Choke coils are not to be recommended for use in connection with cables as a protection against surges, as the combination of inductance and capacity in series which is thus obtained is liable to produce a resonant condition resulting in serious rises of potential and thus defeating the exact purposes in view.

In general the grounding of a neutral point of a system has the effect of preventing many static disturbances. Even on very high voltage overhead lines of great length the grounding of the neutral at the power house through a resistance, even of considerable ohmic value, has been found to eliminate the flashing over of transformer bushings and station inlets to such a degree as to make it well worth while, notwithstanding some inconvenience which it may at times cause due to the tripping out of the circuit in case of grounds on one line of the circuit.

PERSONNEL OF OPERATING FORCE

While comparatively little can be said on the subject of the operating organization that will apply to all conditions, it is nevertheless true that a complete, well trained and enthusiastic organization is

*This is discussed in an article on "Protection of Electric Circuits and Apparatus from Lightning and Similar Disturbances" in THE JOURNAL for February, 1908, pp. 84-86. See also articles by Messrs. Fortescue and Peck (and editorials) in the present series appearing in the March and May, 1911, issues.

an effective weapon against service interruption. It is obvious that the assumption should not be made that conditions will always be perfect. Possible contingencies should be foreseen and the men instructed and trained as to what to do and how to do it quickly and accurately. Sometimes valuable time is lost by men working at cross purposes because of misunderstanding. The maintenance of an efficient organization involves peculiar difficulties, as the personnel is likely to be constantly changing and a great deal of the work of training the men must frequently be repeated. The loyalty, enthusiasm, resourcefulness and carefulness of operating attendants and linemen is a great factor not only in the prevention of interruption but more particularly in the reduction of the length of time for which those that do occur may continue.

The disturbance which produces an interruption and interferes with the regular routine also involves the possibility of injury to operating men or assistants. The quality of the men composing the organization and the care with which they are trained and instructed is the best preventive against accidents.

SUMMARY

It is obvious, then, that many diverse elements must be considered in maintaining service with the least interruption. There is no panacea for all the troubles of power transmission systems nor can any equipment or installation be worked out so completely as to eliminate accident, or the "personal equation."

The best designed and best conducted systems will meet with accidents at times, but on the whole, if proper care is taken and the best skill employed in making up the material equipment, and if eternal vigilance and preparedness is insisted upon, its return will be in the form of increasingly reliable service.

CHARACTERISTICS OF CURRENT TRANSFORMERS

HAROLD W. BROWN

Although current transformers are fundamentally the same as other transformers in their general characteristics, there are several features which are particularly applicable to their action. The principles as discussed below apply without modification to both single and polyphase alternating-current circuits. The present paper is introductory to a later discussion of various connections of current transformers on three-phase, three-wire and four-wire circuits.

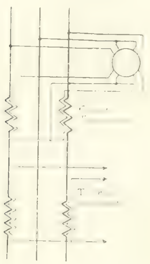


FIG. 1—SEPARATE PAIR OF CURRENT TRANSFORMERS CONNECTED TO A WATTMETER OR WATT-HOUR METER, TO GIVE INCREASED ACCURACY

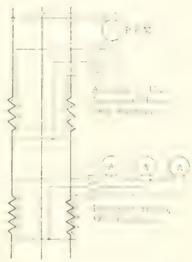


FIG. 2—INSTRUMENTS HAVING ONLY REACTANCE MAY BE IN SERIES WITH A POWER-FACTOR METER, AND INSTRUMENTS HAVING ONLY RESISTANCE USUALLY INTRODUCE SMALL ERRORS WHEN IN SERIES WITH AMMETERS

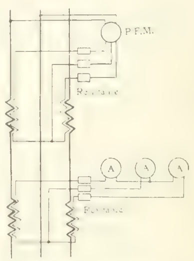


FIG. 3—SHOWING WRONG ARRANGEMENTS WHICH INTRODUCE ERRORS IN POWER-FACTOR METER AND AMMETER

Short-Circuited Secondary—If the current transformer secondary is nearly short-circuited, the ratio of secondary to primary current is very nearly equal to the ratio of primary and secondary turns. This is illustrated in Fig. 1, where only a wattmeter or watt-hour meter of low impedance is connected in series with the transformers. Such a connection is desirable where the watt-hour meter is used for making charges for energy, especially if the normal line current is much less than the rated current of the transformer,

because the percentage of error due to impedance is greatest at small currents.

Resistance and Reactance in Secondary—When any impedance is introduced in the transformer secondary circuit, there is an error in the current *ratio*, which in ordinary service depends mainly on the reactance that is introduced. Resistance ordinarily has less effect on the ratio but introduces a phase discrepancy between primary and secondary current, whereas reactance has a negligible effect on phase relation. Both of these errors are small with ordinary grouping of measuring instruments. Thus a coil of considerable reactance may be placed in series with a power-factor meter, but should not be put in series with an ammeter; whereas an instrument having only resistance would have less effect on the ammeter, but more on the power factor meter indications. See Figs. 2 and 3.

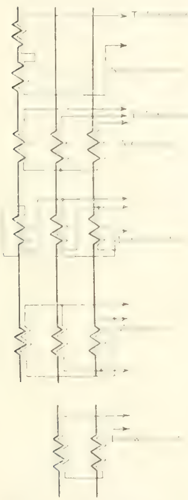


FIG. 4—ALLOWABLE CONNECTIONS
These do not introduce excessive voltages.

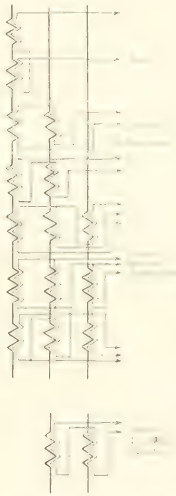


FIG. 5—WRONG CONNECTIONS
All of these may introduce excessive voltages.

Effect of Large Impedance—If the impedance (whether it consists mainly of resistance or reactance) is large, the error in current ratio is correspondingly large, and the voltage between transformer secondary terminals may be considerable. An open circuit on the secondary is an example of extremely high resistance, and the voltage in this case may be so high as to endanger the operator and put an excessive strain on the transformer insulation.

Inter-Connected Secondaries—If the secondaries of two or more current transformers are connected together in such a way that the current from one or more transformers must return through

another transformer, the resulting voltage may be dangerously high and an excessive error in current ratio will be introduced unless the current returning through the latter transformer is the same in phase and amount as would be induced in it by its primary current. Fig. 4 illustrates several allowable connections. The series, delta, and two-wire connections can be made also on four-wire and grounded neutral circuits. The connections shown in Fig. 5 are wrong. They are liable to introduce excessive voltages in the secondary circuits.

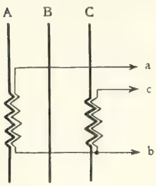


FIG. 6
Current in secondary common line b is proportional to current in primary line B.

Current in Common Return—If any circuit has a current transformer in every line except one, which may be designated as B, and all the secondaries have their circuits completed through a single common return wire, the total current in the return wire is the same in phase and amount as the secondary current would be in a transformer connected in line B, *provided;* first, that there is no primary ground, or other return circuit for the primary, except the lines just mentioned; second, that the current transformers all have the same current ratio, and third, that the secondary common return connects to corresponding transformer leads, on all the transformers, i. e., to the lead from each transformer at the outgoing end. These conditions are illustrated in Figs. 6 and 7.

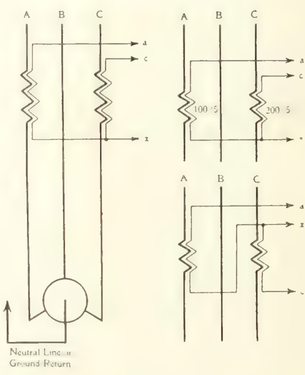


FIG. 7
Showing connections in which current in secondary common line X is not proportional to current in primary line B.

Secondaries in Series or Parallel—If two or more current transformers on the same line of the same circuit have their primaries in series, and their secondaries are properly connected in series, as indicated under *"Inter-Connected Secondaries"* above, the secondary current is the same as if there were only one transformer, except that if there is an appreciable error in current ratio or phase displacement the error becomes smaller as the num-

ber of transformers is increased. If the primaries are in series and the secondaries in parallel, the total secondary current is increased in proportion to the number of transformers. Thus, in Fig. 8, with the two secondaries in series, the secondary current is five amperes; and in Fig. 9, with the same primary current and with the secondaries in parallel, the secondary current is ten amperes.

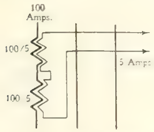


FIG. 8 — PRIMARIES IN SERIES; SECONDARIES IN SERIES

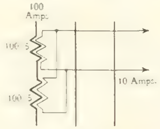


FIG. 9 — PRIMARIES IN SERIES; SECONDARIES IN PARALLEL

Light Load Errors—There is an error in current ratio at small currents, especially if the impedance in the secondary is large. This is illustrated by the curve, Fig. 10, which shows the percentage of the correct ratio that a typical transformer has at different currents.

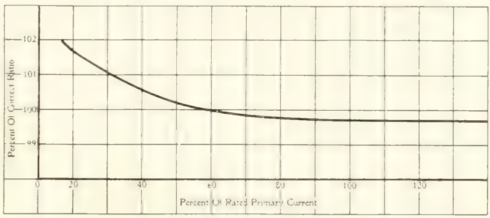
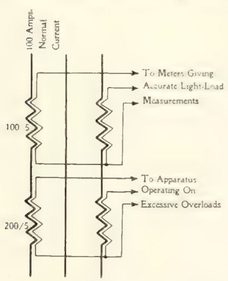


FIG. 10—TYPICAL RATIO CURVE OF CURRENT TRANSFORMER

The transformer here considered is compensated so that it has correct ratio at 60 percent of its rated current. It will be seen that the percent of error is small above 60 percent, but becomes larger as the current is decreased. If great accuracy is required, the transformer should be of such capacity that the normal load is between 50 and 100 percent of the rating of the transformer, to avoid light load errors and overloading the transformer. As is illustrated in Fig. 11, it is sometimes advisable to provide a separate pair of transformers to secure especially accurate indications on certain meters, where the other instruments require a transformer of large current rating, because the transformer having the larger current rating has a greater light load error.



FIR. 11—SEPARATE PAIR OF TRANSFORMERS TO SECURE ACCURATE LIGHT-LOAD MEASUREMENTS ON METERS

WINDING OF DYNAMO-ELECTRIC MACHINES—XIV

CONNECTIONS FOR DIRECT-CURRENT ARMATURE WINDINGS

H. C. WALTER

DIRECT-CURRENT armature windings may be classified under two general types, namely, open and closed coil windings. Open coil windings are limited in their application to constant-current dynamos, while closed coil windings have a much wider field of application, as they are used in practically all constant potential generators and motors. Closed coil windings are sub-divided into two classes, viz., ring windings and drum windings, of which the latter are used almost exclusively at the present time, the ring winding having become almost obsolete. In the present article the purpose is to consider only connections for closed coil drum windings, as they are by far the most important of all types of direct-current armature windings.

For the sake of clearness the following terms most commonly applied to the armature windings will be defined.

Armature Coil—All the conductors on the armature connected in series between two consecutive connections to the commutator. It may consist of one or more turns.

Winding Element—One side or half of a coil. it may consist of any number of turns.

Coil Pitch—The distance between two sides of a coil, measured in elements.

Back Pitch—Same as coil pitch, but measured most conveniently at the back end of the armature.

Front Pitch—The distance between two elements connected to the same commutator bar measured in winding elements, but measured most conveniently at the front end of the armature.

Commutator Pitch—Distance between the two commutator bars connected to the ends of a coil, measured in commutator bars.

Drum windings may be divided into two distinct types, the lap or multiple winding and the wave, or series winding.* The difference in the construction of the two types pertains to the method of connecting together the individual coils, they being easily distinguished by an inspection of the end connections. In the wave winding the end connections at the front and rear of the armature continue in the same direction around the armature as shown in Fig. 152, while in the lap winding the front and rear connections lead in opposite directions, as shown in Fig. 153.

*See introductory article by Mr. R. A. Smart, June, 1910, p. 454.

In determining the number of coils to be used in an armature winding there are certain rules that must be observed, which are briefly as follows:

1—The front and back pitch must both be odd numbers, and in the lap winding must differ by *two* or some multiple thereof.

2—In the wave winding the front and back pitch may be equal or may differ by *two* or some multiple thereof, as above.

3—In the lap winding the front and back pitches are of opposite sign, that is, they are laid off in opposite directions on the armature, while in the wave winding they are of the same sign.

4—The commutator pitch is equal to the average of the front and back pitches.

In applying these rules and the formulæ which follow, it is necessary, when slotted armatures are used, to adhere to a definite method of numbering the elements of the windings. Since the coils are always arranged in two layers, in slotted armatures, the elements forming the top layers are designated by odd numbers and those in the bottom layers by even numbers, as shown in Fig. 154. This convention is followed in the case of all of the slotted armature diagrams here considered.

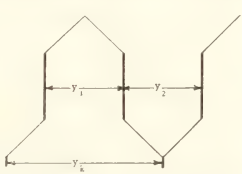


FIG. 152—WAVE OR SERIES WINDING

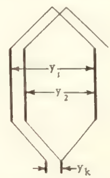


FIG. 153—LAP WINDING

LAP WINDINGS

For the lap winding, Fig. 153; back pitch $= y_1 = \frac{s \pm b}{2p}$; front pitch $= y_2 = y_1 \pm 2$; average pitch $= y = \pm 1$; commutator pitch $= y_k = \pm 1$, where $s =$ the number of half coils or elements in the winding, $p =$ the number of pairs of poles in the machine, and $b =$ a number which will make y_1 and y_2 odd integers (whole numbers).

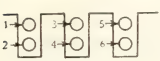


FIG. 154

For $b = 0$, the back pitch becomes equal to the pole pitch; if b is positive, y_1 becomes greater than the pole pitch; if b is negative, y_1 becomes less than the pole pitch. As a rule b is negative, y_1 becomes less than the pole pitch. As a rule b is always taken negative, i. e., y_1 is made equal to or less than the pole pitch.

The simple lap winding has as many parallel circuits as there are poles in the machine. However, in cases where it is necessary to obtain a very heavy current, double or triple lap windings are

sometimes used. The double lap winding is obtained by placing two similar windings on the same armature and connecting the even numbered commutator bars to one winding and the odd numbered ones to the second winding. Similarly, in the triple lap winding, each section of the winding would connect to one-third of the commutator bars. For these windings, $y_1 = \frac{s \pm b}{2p}$; $y_2 = \frac{s \pm b}{2p} \pm 2m$; $y_k = \frac{y_1 - y_2}{2} = \pm m$; $y = y_1 - y_2 = \pm 2m$, where m = an integer greater than *one,* i e., *2* for a double winding, *3* for a triple winding, etc. If the number of commutator bars is exactly divis-

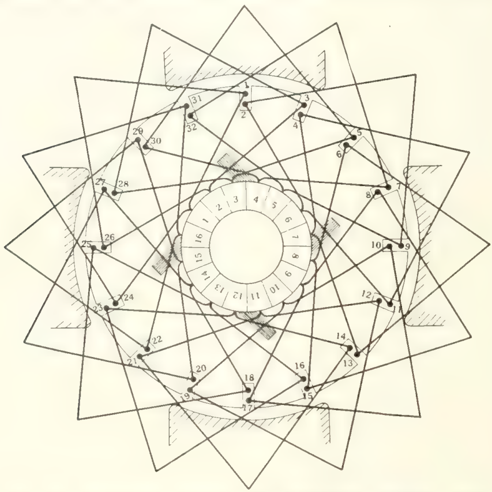


FIG. 155—FOUR-POLE, SINGLE LAP, MULTIPLE CIRCUIT, FULL PITCH WINDING

ible by m, the several windings will be entirely separate from each other.

A four-pole lap or multiple winding of 16 coils in 16 slots is shown in Fig 155, for which $s = 32$, $b = 4$, $p = 2$. Then, $y_1 = \frac{32-4}{4} = 7$, and $y_2 = \frac{32-4}{4} + 2 = 9$. In this winding the coil pitch y_1 is equal to the pole pitch; it is, therefore, a full pitch winding.

A multiple winding in which the coil pitch y is considerably less than the pole pitch is shown in Fig. 156. In this case $s = 64$, $b = 12$, $p = 2$, z, the number of slots $= 16$. Then, $y_1 = \frac{64-12}{4} = 13$ and $y_2 = 13 - 2 = 11$. This style of winding is generally

known as a chord or chorded winding, in distinction from the full pitch winding.

A double lap winding composed of 36 coils placed in 18 slots and 18 coils for each winding, is shown in Fig. 157. In this case $s = 72$, k, the number of commutator bars, $= 36$, $2p = 4$, $m = 2$. Since in this case $\frac{s}{2p}$ is an even number, $= 18$, b is taken as 4; hence, $y_1 = \frac{72-4}{4} = 17$, $y_2 = 17 - 4 = 13$, and the commutator pitch, $y_k = \frac{17-13}{2} = 2$. Since the number of commutator bars ($= 36$) and

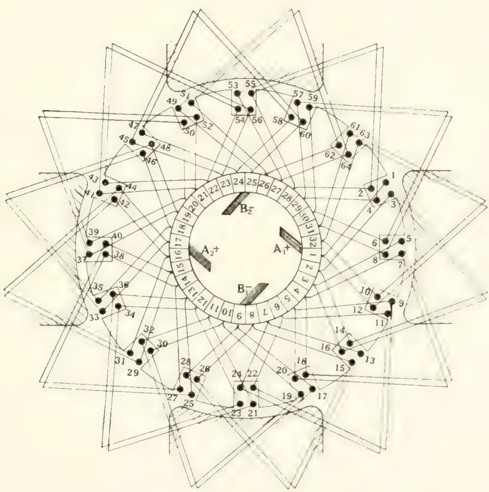


FIG. 156—FOUR-POLE, SINGLE LAP, CHORD OR FRACTIONAL PITCH WINDING

the commutator pitch, ($y_k = 2$) have the common divisor *2* two distinct windings are obtained. Beginning with bar *1* and tracing through the winding it may be seen that the winding completes itself after going around the armature once and connecting to one-half of the commutator bars; this winding has $2p = 4$ parallel circuits. Similarly the second winding embraces one-half of the coils and commutator bars, its coils fitting in between those of the first winding, and has also four parallel circuits. The two windings together, therefore, give eight parallel circuits.

WAVE WINDINGS

For the wave windings, also called series or two-circuit windings, of the type shown in Fig. 152, the following formulæ are obtained: $y = y_1 + y_2 = \frac{s \pm 2}{p} = 2\,y_k$; $y_k = \frac{y_1 + y}{2} = \frac{k \pm 1}{p}$. Hence, the number of commutator bars must satisfy the equation, $k = p \times y_k \pm 1$. As before y_1 and y_2 must be odd integers and y must be a whole number. In this case the back pitch is very nearly equal to the pole pitch and the sum of the front and back pitches is very nearly equal to double the pole pitch. If y_1 is de-

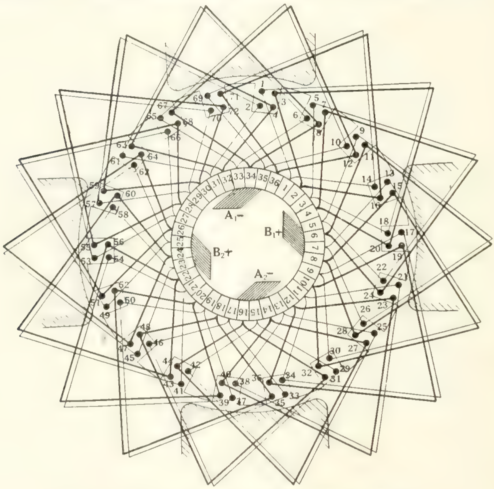


FIG. 157—FOUR-POLE DOUBLE LAP WINDING

creased, as in the case of a chord winding, then y_2 must be increased so that the sum $y_1 + y_2$ remains constant.

A four-pole series or wave winding of 13 coils is shown in Fig. 158, in which $y_k = 6$, $2p = 4$. Then $k = 2 \times 6 \pm 1 = 11$ or 13 (in this case 13), and $y_1 + y_2 = 2y_k = 12$, for $k = 13$, $s = 26$, $y_1 = 7$, $y_2 = 5$. Beginning with bar No. *1* and element *1* and tracing through the winding element, No. *1* connects with $(1 + y_1 = 1 + 7 = 8)$, elements *1* and *8* forming the two sides of a coil. As the commutator pitch is $(y_k = 6)$ and the front pitch 5, from element No. 8 the circuit passes across the front end of the armature to element $(8 + 5 = 13)$ and in so doing connects to commutator bar

$(1 + 6 = 7)$. Continuing around the armature through the coil formed by elements *13* and *20* and then to commutator bar $(7 + y_k = 13)$, the circuit is found to have traveled around the commutator a distance of $2y_k$ bars and reached the bar $(1 + py_k)$ at a distance of one bar from the starting point. Denoting by m the amount which y_k differs from the double pole pitch (in this case half a bar), $p\,m = 1$ is the amount by which py_k (or $2y_k$) deviates from the starting point, bar No. *1*. Then $py_k = k \pm pm$, or, since $m = \frac{a}{p}$, $y_k = \frac{k \pm a}{p}$, where a is the number of pairs of parallel

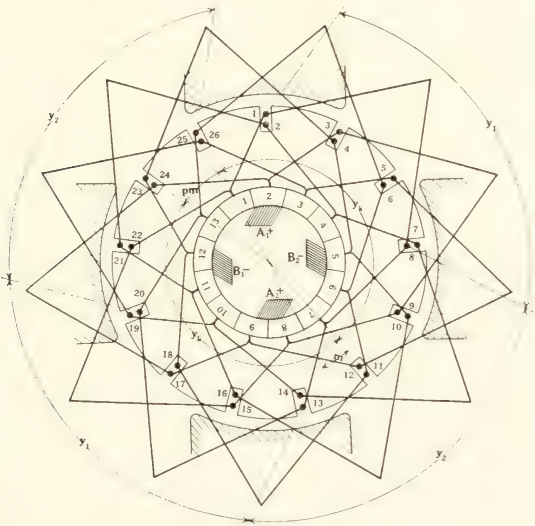


FIG. 158—FOUR-POLE, TWO-CIRCUIT, WAVE WINDING

circuits in the armature. In this type of winding the number of parallel circuits in the armature is *two,* regardless of the number of poles. This winding is particularly well adapted for small and moderate sized machines where it is desirable to keep the number of coils as small as possible.

Practically all of the important armature windings for large and moderate sized direct-current machines are covered by the foregoing. The method of winding small hand-wound machines has been given in a previous installment of this series.*

*See June, 1910, p. 460, and July, 1910, pp. 547 and 553.

EXPERIENCE ON THE ROAD

A PHANTOM LOAD

LEONARD WORK

CIRCULATING CURRENT between alternators in parallel may result from a variety of causes, chief among which is a tendency toward unequal generator speed, the latter resulting from slippage or bad joints in belts, difference in pulley diameters, angular variation in prime movers and super-sensitive or faulty engine governors. There are other less frequent causes which are sometimes difficult to discover. Quite recently there happened a case of this latter kind which is of particular interest, not only because of the unusual and perplexing cause of the trouble, but because of the liability of its happening wherever similar conditions prevail.

Two 150 kw, two-phase alternators of the revolving armature type were reported as indicating on their ammeters a quiet, steady current of about half load on each machine when run in parallel without any load connected to the bus-bars, but when either machine alone was run in parallel with an incoming power line, which came in through transformers, no such effect could be seen.

The trouble was said to date back but a short period to when one of the generators had a number of armature coils replaced. Subsequent to these repairs an increase in station load required the operation of both generators. The evidence of unbalanced circulating currents seemed to be very strong and convincing, and, therefore, an examination of the offending machine was immediately begun. The armature winding was of the closed-coil type with taps brought out mechanically and electrically at points 90 degrees apart. The windings and connections were traced out and checked several times and proved to be absolutely correct and precisely like those of the other generator, so it was obvious that, whatever was causing the trouble, the repaired armature coils were surely not responsible, and therefore this clue, which at first was so promising, had to be abandoned. Tests were then made to eliminate all the usual causes of circulating current, such as slipping of belts and friction clutches, etc., but in these respects everything was found normal and in good condition. Voltages on the phases of both machines registered alike.

Circulating current or a phantom load, such as was observed

in this plant, can be produced with two alternators in parallel when the field of one unit is under or over-excited, the proper adjustment being reached when, upon manipulating the field rheostats without altering the bus-bar voltage, the total generator amperes are at a minimum; but here no field adjustment could be found which would reduce the apparent load. Both of the generators were of the compensator type, in which an induced current proportional to that in the main leads is rectified by a commutator and circulated around the fields, the effect being similar to that of the compound winding of a direct-current machine. It was believed that there was a possible chance for trouble here, although it did not seem likely, especially at no-load. However, a test was made with all the compensator circuits on both machines cut out, but this had not the slightest effect on the trouble.

The steadiness of the phantom load was such as to excite suspicion that some kind of apparatus might be connected to the generators or bus-bars unbeknown to the attachées of the plant, and although repeated tracing out of leads and switchboard wiring revealed no such connections, in order to make double sure, the lines of the switchboard were disconnected and the machines paralleled through temporary wires straight from one unit to the other. After this was done an ammeter inserted in the circuit showed that the exasperating circulating current was still present. Every attempt on the part of the investigating engineer to discover a solitary symtom of disorder had gone down in defeat, and as apparently all other possible tests had been made, saturation curves were taken, but these threw no new light on the question.

The capacity of the plant was so materially reduced by the circulating current that the engineer was urged to try again to locate the source of the trouble, but it was only after considerable persuasion that he was induced to make another trip to the distant city to investigate anew. Again taking up the thread of investigation, and reflecting that an exchange current between machines could be caused only by super-imposing or combining two voltage waves of unequal value, it was evident that this was what was taking place here, but from some cause as yet obscure. Means for measuring or comparing the waves of the machines were lacking; however, in the absence of an oscillograph, it was finally decided to investigate in a somewhat crude manner the main and side circuits of each alternator separately by means of an incandescent lamp, which, when connected while the machine was run slowly,

would keep pace with the alternations in brightening and darkening with each wave of voltage. The alternations of the machines were readily followed and in each case the pulsations on both phases were found to be normal. However, upon connecting to a side circuit of one of the machines, i. e., to one lead from each phase, a peculiar effect was noticed. Coincident with each revolution of the armature the waves could be seen to attain a maximum and minimum; the intensity of the flashes ascending and descending with each revolution. This indicated almost as clearly as an oscillograph could have done that the e.m.f. in this section of the winding rose and fell at one particular place instead of being constant as in the other machines. The reason for this irregularity could only be due to lack of uniformity in the strength of the magnetic flux around the armature.

Investigation as to the cause of the difference in field strength developed the fact that the air-gap at the upper portion of the field was almost twice as great as at the lower part, and this was the cause of the rise and fall of potential in the side circuits previously mentioned. This effect, because of its being super-imposed with the voltage of the side currents of the other machine whose potential did not vary, caused at every revolution a surging back and forth of current in the lines paralleling the machines, which, however, at full speed registered on the ammeter as a steady current.

The remedy was obvious. Steps were taken at once to shim up the bearings, in order to raise the armature to the center of the air-gap. When this work had been completed, both machines were started and paralleled. That the trouble which so long had remained a mystery had been found and removed was now apparent, for at no-load the ammeters did not indicate any current.

The important fact brought out by this experience was that circulating current between alternators in parallel may result from an unbalanced air-gap when the machines are of the closed coil type of winding.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal Box 911, Pittsburgh, Pa.

569—Temperature and Rating of Induction Motors—At what temperature does the insulation of an induction motor commence to deteriorate? The motor is a three-phase, 60-cycle, 440-volt machine. Is 65 degrees C. hot enough to harm the insulation? What is the difference, if any, in the hp rating of a 30 hp induction motor which was built by the manufacturers as a 30 hp open type machine and afterwards used semi-enclosed? What load would it safely carry without overheating? J.O.F.

The insulation should not be subjected to an ultimate temperature of more than 90 degrees C. With an initial temperature of 25 degrees C. this would represent a safe temperature rise of 65 degrees. A 30 hp motor, normal open rating, if operated entirely closed, would ordinarily be good for about 15 hp in continuous operation. If semi-enclosed the rating would probably vary from 20 to 25 hp depending upon the degree to which its ventilation was reduced. M.W.B.

570—Application of Alternator to Power-Factor Correction—It is desired to use a spare 150 kw generator as a synchrouous motor, to carry a load of about 100 hp, and at the same time correct the power-factor of the induction motor load which is carried by a 400 kw generator of the same voltage and frequency. The power-factor is about 70 percent at present. What changes would it be necessary to make in this alternator for such an application, and to what extent would it correct the power-factor? What size and arrangement of motor would be required to start the synchronous motor. The latter is rated, as a generator, at 550 volts no-load, 580 volts full-load (compounded), 12 poles, 600 r.p.m., 150 amperes per terminal. T.J.B.

Comprehensive information covering this question will be found in the answers to the following questions and the JOURNAL articles referred to in connection therewith: Nos. 366, 425, 470 and 481. If further assistance is required in making preliminary calculations for this application additional information should be furnished as follows: Give maximum current which field will carry with a maximum rise of 60 degrees C. Give short-circuit curve, i. e., values of field current in amperes plotted against values of armature short-circuit current. Give no-load saturation curve, i.e., with armature open-circuited, plot values of voltage obtained with varying excitation against corresponding values of field current. (The method of carrying on these tests is given in articles on "Factory Testing" referred to in No. 481.) Without this information it would only be possible to approximate the probable performance of the 150 kw alternator under the proposed application. A ten-pole starting motor should be employed. If the synchronous motor is to be started and synchronized with external load, the starting motor should be capable of developing about 500 ft.-lbs. starting torque and of carrying the no-load losses of the large motor at its synchronous speed for approximately ten minutes. If the small motor is required to start and accelerate any line shafting or additional machinery up to the synchronous speed of the large motor, the amount of additional starting torque and power required should be included. R.A.S. AND M.W.B.

571—Automatic Potential Regulator Employing Carbon Piles—The following arrangement is pro-

posed as a means of regulating automatically the potential of a 2 300 volt, single-phase distributing circuit: A booster transformer will be connected in series on one side of the 2 300 volt line, the secondary of this transformer being connected at the middle point of an auto-transformer, shunted across the low-tension (220 volts) side of the distributing circuit, and also connected in series with each of two carbon piles by means of a common connection between them. The remaining terminal of each carbon pile will be connected to the 220 volt line, one on either side of the line. A solenoid-operated lever will be provided, by means of which either of the carbon piles may be subjected to compression, thus increasing the conductivity. The solenoids for doing this work will be controlled by means of two potential relays, the action of which will depend upon the voltage of the 220 volt circuit. In this way a boosting or bucking effect may be obtained at the booster transformer, as the conditions may require. Do you consider that this would be a practical method of obtaining voltage regulation? A.A.J.

Carbon piles, particularly when carying much current are not reliable for constant resistance. With the proposed arrangement they would dissipate considerable energy. Assume the regulator to be in the neutral position, with full-load current on the line; then this same current would, of course, flow in the primary of the booster transformer, thus tending to cause current to flow in its secondary circuit and in the two parts of the resistance and the two halves of the auto-transformer to the 220-volt line. The entire arrangement would be very inefficient as it would act as a combined choke coil and resistance. E.E.L.

572—Effect of Pitch Winding—In some induction motors, the winding of the stator has four coils in series per pole, the span of the coil being 1 and 10 and sometimes 1 and 13. What difference does it make whether the coils of a three-phase motor, for example, are spanned 1 and 10 or 1 and 13? B.W.O.

The effect of reduced span of the coils is the same as a reduction in the number of turns, although the effect is not in direct proportion. As decreased primary turns on a given motor means higher torque, reduced power-factor, increased magnetizing or no-load current, etc., a similar result is obtained by reducing the span of the coils. This variation in the span gives a very flexible means for getting the equivalent of variation in the number of turns, so that by changing the span of the coil, different performances can be obtained when using the same number of turns per coil, and conversely the same performance may be obtained by using the shorter span with an increased number of turns. Furthermore, in some cases, very considerable gain in end space is effected by shortening the span. This applies particularly to machines with a small number of poles. Thus, provided the number of slots, size of wire, number of turns, and the connections of groups remain unchanged, a motor with a throw of 1 and 10 will have greater available torque than one having a throw of 1 and 13. The increase in torque, however, is obtained at the expense of power-factor. For a given performance the throw of the coil is determined by the best possible arrangement of the winding in the slot. Accordingly, by varying the number of turns per coil, the same performance may be approximated on different machines having different throw of coils. See article on "Winding Connections of Alternating-Current Machines," in the JOURNAL for May, 1911, p. 468. M.W.B.

573—Reconnection of Induction Motor for Change of Speed—In a five hp, two-phase, 60-cycle, 440-volt induction motor, with a speed of 1 800 r.p.m., there were three coils per pole, four poles per phase. When running with no-load the motor took about two amperes per phase. It was re-connected for 1 200 r.p.m., two coils per pole, six poles per phase. The required speed was obtained but the motor took 15 amperes per phase when running with no-load; it was therefore changed back to the original

connection. Please advise as to the cause of this abnormal current.
R. MCK.

To maintain the same no-load current, when rewinding for change of speed, the number of phases being unchanged, the number of series turns per phase should be increased or decreased in the same ratio as the number of poles. Assuming that all the groups were in series for the 440 volt, 1 800 r.p.m. connection, then to give the same no-load amperes with the 440 volt, 1 200 r.p.m. connection, the number of turns per coil should be increased by the ratio of 6:4. It should be noted that decreasing the pole pitch (equal to the total number of slots divided by the number of poles) without a corresponding decrease in the pitch of the coil has the same effect as decreasing the pitch of the coil without changing the pole pitch. In other words, a winding of 125 percent pitch has the same effect as a winding of 75 percent pitch, and may be considered as a fractional pitch winding. The combined effect of the fractional pitch feature just considered and of decreasing the speed without increasing the number of turns, will be to greatly increase the density of various portions of the magnetic circuit. If that portion of the iron which is most effected is worked close to saturation for the four-pole connection, it will be highly saturated with the six-pole connection. The result of these three conditions will be to greatly increase the no-load (magnetizing) current of the six-pole connection over that of the four-pole connection, and the increase noted in the question is therefore what might be expected with the windings changed as stated therein.
W.M.B.

574—Secondary Current of Induction Motor—Given a 125 hp, three-phase, 30 cycle, 2 000 volt constant speed motor, of the wound secondary slip ring type, how may the secondary current per ring be obtained. Please explain the various quantities which would be used in the formula.
R.F.H.

Roughly speaking, under certain conditions, the secondary current per phase is constant for a given torque irrespective of the speed of the motor. Hence if the current is calculated for a given torque at any speed it holds for the normal full-load speed, or for any other speed within the range of the motor. Consider, then, the locked condition, with the secondary short-circuited through the proper resistance to give a torque corresponding to the normal running torque. The motor then becomes a polyphase transformer delivering no mechanical power, but electrical energy which is absorbed in the external resistance. The secondary current per phase is easily computed, by knowing the open-circuited secondary voltage (determined by impressing normal voltage on the primary and measuring the open-circuit voltage between secondary rings with the rotor stationary, and the normal full-load slip, since the latter is proportional to the secondary losses and hence determines the efficiency of the winding. Assuming a four percent slip, which corresponds to a secondary efficiency of 100—4 or 96 percent, the product of hp output $\times 746 =$ volt-ampere output. This VA output $\div$ sec. eff. $=$ sec. input. If the secondary is connected three-phase, its VA input $\div$ ($1.73 \times$ sec. volts) $=$ sec. amperes per ring. If the secondary is two-phase, the VA input $\div$ ($2 \times$ sec. volts) $=$ sec. amperes per ring, in the case of two-phase, four-wire circuits, and in the outside wires of two-phase, three-wire circuits; for current in the neutral of two-phase, three-wire circuits, multiply this value by 1.41.
M.W.B.

575—Speed of Wound Rotor Induction Motor—A three-phase motor is running at full speed on no load. With one of the rotor lines disconnected, the speed remains unaltered. Load is thrown on and the speed sinks to just half synchronous speed. Load is taken off but the speed instead of rising to full speed still remains at half speed.
C.B.D.

With one secondary circuit open the resulting single-phase winding gives an arrangement of the secondary magnetic circuits such that the motor is caused to operate at one-half synchronous speed. This action

is described in articles on "The Polyphase Induction Motor," and "Some Phenomena of Single-Phase Magnetic Fields" by Mr. B. G. Lamme in the JOURNAL for Nov., '04, p. 599 and Sept., '06, p. 492. As noted on p. 599, when operated thus at half-speed the power-factor and efficiency are both low. Due to some peculiarity of design some wound secondary induction motors will exert enough torque at standstill to start without load and reach synchronous speed with the secondary circuits open. This torque is developed from the eddy currents in the iron and sometimes from the secondary winding itself if there are circuits in parallel which are slightly out of phase. The motor in question probably possesses this open-circuit torque of a sufficient amount to keep it running without load after having been brought up to speed and one secondary having then been opened. When the load is impressed the speed immediately falls on account of insufficient torque, until the half-synchronous speed is reached, when the operation is as has been outlined above. For further information see article by Mr. G. H. Garcelon on "Polyphase Motors on Single-Phase Circuits" in the JOURNAL for Aug., 1905, p. 501. M.W.B.

576—Adjustment of Tirrill Voltage Regulator—Should a type T. A. Tirrill voltage regulator be adjusted so that if contacts were to "hug" together, the voltage would rise to say 1 500 volts on an 1 100 volt machine, or should it be so adjusted that at an average high load the voltage could not gain to, say, over 1 200 volts? Of course, in the latter case, if the regulator failed to close, the voltage would fall to a point where motors would probably pull out. A.G.W.

The proper adjustment for field rheostats for all Tirrill regulators, including type *T.A.*, form *A*, should be such as to give the maximum alternating-current voltage obtainable when the relay contacts of the regulator are closed. This would be done by cutting out all of the resistance in the field rheostat of the alternating-current generator and introducing sufficient resistance in the exciter field rheostat to cause the alternating current voltage to drop from normal to about 65 percent below normal in six to eight seconds. If there is not sufficient resistance in the exciter field rheostat to lower the voltage as indicated a new exciter field rheostat of greater resistance should be used. The operating point of the exciter field rheostat should be marked so that it can always be readily set at this point when the regulator is in service. The adjustment of the exciter field rheostat should be made when there is no load on the generator and, in fact, no current flowing out of the station. Then the regulator should be allowed to operate at normal voltage and the switch at the bottom of the regulator which puts it into service should be open and the time taken; this adjustment being repeated until a time interval of six or eight seconds is required for the voltage to fall from normal to 65 percent of normal value. If the Tirrill regulator is properly adjusted it will not fail to operate properly at all times, so that there is no danger of the motors falling out, due to the action of the regulator if the above adjustments are made. A.A.T.

577—Meter Equipment for Industrial Plant—Please suggest a combination of meters suitable for a 500 kw, three-phase, 60 cycle, 220 volt, manufacturing plant where it is desired to obtain peak motor watts, unit costs per day and power-factors of installations. The motor capacities range from one-half to 25 hp, there being no installation of over 40 kw capacity that could not be sub-divided. A.G.W.

For carrying on these tests the following instruments would be required: One alternating-current portable volt-meter with a range of about 140 and 280 volts; three alternating-current ammeters of 200 amp. capacity; three alternating-current portable ammeters of 100 amp. capacity; three alternating-current portable ammeters of 60 amp. capacity; three alternating-current portable ammeters of 20 amp. capacity; three alternating-current portable ammeters of ten amp. capacity; three alternating-current portable ammeters of five

amp. capacity; three alternating-current portable ammeters of two and one-half amp. capacity, three single-phase or one polyphase portable wattmeter, each of the above current capacities and with suitable voltage windings. The most economical way of arranging for ammeters and wattmeters of the above capacities is to have only one set of meters (that is, three ammeters and one polyphase wattmeters) which should each be wound for two current capacities, viz., two and one-half and five amperes. Use, in connection with these, two sets of portable current transformers. Two transformers of a given capacity would be sufficient and they should be multiple-ratio transformers. One pair of multiple-ratio transformers would be required for the larger capacities and one pair for the smaller capacities. The same transformers would answer for both ammeters and wattmeters. In this connection note article on "Investigating Manufacturing Operations with Graphic Meters," by Mr. C. W. Drake, in the JOURNAL for July, 1910, p. 536. H.B.T.

578—Reversal of Wattmeter—Would a polyphase integrating wattmeter connected in the standard way on a three-phase circuit with a load of less than 50 percent power-factor reverse its direction of rotation if one side of the line

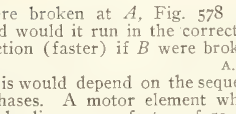


FIG. 578 (a)

were broken at *A*, Fig. 578 (a), and would it run in the correct direction (faster) if *B* were broken? A.G.W.

This would depend on the sequence of phases. A motor element which, on a leading power-factor of 50 percent or less, would reverse under the conditions noted in the question, would rotate forward (faster) if the power-factor were 50 percent or less leading. For example, if the sequence of phases is such that the current in *A* lags behind the voltage across phase *AC* at 100 percent power-factor, the motor element in this phase will reverse at a power-factor of 50 percent or less lagging current. See article on "Polyphase Wattmeter Connections," by Mr. M. H. Rodda, in the JOURNAL for July, 1909, p. 436. H.B.T.

579—Carrying Capacity of Galvanized Iron Wire—What sizes of ordinary galvanized iron wire will carry currents of 100, 150, 200, and 250 amperes, respectively, for 20 seconds without heating beyond a dull red, the coils being suspended in air. It is desired to build an emergency resistance for use in starting alternating-current motors. An outfit as light and compact as possible is desired. The starter will be arranged for two steps one for approximately 50 percent of full-load torque and the other for about 75 percent. The capacities of the motors with which this starter will be used are 30 and 60 hp. R.D.C.

For such short periods, radiating effect of the starting resistance is negligible. Hence, all of the heat generated must be considered as absorbed in the material. The following formulas may be used for calculation of the required area of cross-section for a given current, assuming the resistance to be suspended in air. $A = C \frac{Rt}{1070\,WHT}$ in which A = cross-section of wire, C = current, R = resistance of one cubic inch of the resistance material (in the case of iron, = 0.0000082 at 200 degrees F.), T = allowable temperature (for iron, dull red heat would represent about 1 000 degrees F). H = specific heat (of iron = 0.12) W = weight per cubic inch of material (iron equals 0.2779), t = time in seconds current is flowing. Applying this formula, it will be found that, for the large currents involved in the present question, the size of wire will be very large. If the wire were imbedded in some material which readily absorbs heat, such as fine, dry sand, the size of wire could be reduced. The proposed arrangement will be found to be rather bulky at best. It might be found

that cast iron grids, such as are used in railway equipments, would be more effective. They could be immersed in water, as a means of carrying off the heat, and thus a much smaller size and weight of material be employed. It should be noted that at starting, the power-factor of an induction motor is only about 50 to 65 percent, as a result of which a series resistance connected in the primary circuit does not have an effect in proportion to its resistance value. The voltage drop in an impedance of suitable value could, on the other hand, have such a phase relation as to cut down the applied voltage by a maximum amount. Calculation of resistances required to give the desired starting voltage must take these facts into consideration. If the resistances used in connection with the emergency starter were wound inductively they would probably be found to be more effective in obtaining reduction of voltage. The inductive effect of a coil of wire is of course increased by introducing an iron core. H.C.N. AND A.M.D.

580—Electric Heating Calculations—A value of 1 505 600 calories (heat units) is to be used in a certain calculation, the form of equation being, $1\,505\,600 = 0.24\ C^2\ R$, in which $C =$ current, and $R =$ resistance of the heating coil. This becomes $6\,253\,333$ watts $= C^2\ R$. Assuming values of resistance and voltage of the circuit, then by Ohm's law C would be determined. The heat represented by one-fourth of a calorie is equivalent to that given by one watt in one second, or a flow of one ampere, under the pressure of one volt. What is the required voltage and resistance of the circuit? H.F.G

The calculations for such a problem would be made as follows: Given the number of heat units required, calculate the number of watts equivalent to this value of heat units. (As noted in the question, 4 watt-seconds = 1 calorie.) As watts = volts × amperes, in order to calculate the required values of amperes and resistance, the voltage of the supply circuit must be given. Then, amperes = watts ÷ volts; from which the value of resistance may be calculated by the equation, volts ÷ amperes = resistance. Hence, the resistance required will depend on the voltage chosen. F.T.

581—Design of Choke Coils—Please give formula for determining the number of turns required in a choke coil, also the relative advantages claimed for the disc type and spiral type of coil. A.W.B.

A discussion of the amount of choke coil inductance desirable and permissable is to be found in the JOURNAL for Aug. 10, p. 608. A formula for determining the inductance of a choke coil is given in a foot note on page 615. For the ordinary disc type of coil with a diameter about three times the center opening a coefficient of 0.7 should be used with this formula. This is an empirical coefficient obtained by test. There is no fundamental advantage in either the disc or helical coil. The inductance of a coil determines its value, provided its insulation is satisfactory. Heavy inductances can usually be obtained most readily in the disc type, oil insulated form of coil, but any design by which the inductance, and insulation to ground and between turns, can be obtained would be equally effective. R.P.J.

582—Capacity in Alternating-Current Circuit—In the expression for current in an alternating current circuit, we have the following:

$$I = \frac{E}{\sqrt{R^2 + \left(L\,W - \frac{1}{W\,C}\right)^2}}$$

Where $W = 2\,\pi\,f$,

$L =$ inductance, and

$C =$ capacity.

It is well known that in a circuit containing capacity it is possible to have a leading power-factor, and the greater the capacity the greater will be the angle of lead. If, however, in the above expression we increase the value of C, we decrease the value of the last term in the parenthesis, with the result that for very large values of capacity, this term would vanish and the phase of the current would be determined only by the inductance

in the circuit. Conversely if we put C equal to zero, then this term becomes infinite and the whole expression for current reduces to zero. C.C.W.

The above formula applies only to resistance, inductance and capacity in series. In that case it is obvious that zero capacity means zero current and infinite capacity is equivalent to a short-circuit of the condenser element altogether and its effect vanishes. If the capacity is in parallel with the inductance and resistance it is simplest to treat it as a separate circuit and find the condenser current which may then be vectorially added to the other current. If a transmission line and the effect of its capacity, inductance and reactance on voltage drop and power-factor are being considered it must be remembered that all of these factors are *distributed* and part of the capacity is to be considered as in parallel and part in series with the other elements. The equations for this condition are very complicated and it is sufficiently accurate for all except those requiring extreme accuracy to consider the capacity as concentrated in lumps. One way is to assume it all at the middle of the line, another to assume one-half at each end and a still more accurate method is to assume one-sixth at each end and two-thirds in the center of the line. To determine its effect by the first method, for example, a load must be assumed of a certain power-factor at the receiving end. This load current will produce an easily calculated drop in the second half of the line. This drop will have a certain phase angle in relation to the current and receiving voltage and should be vectorially added to the receiving voltage to give the voltage delivered to the second half of the line by the first half. The total capacity of the line assumed as concentrated at its center may then be considered and the capacity current calculated at the voltage above determined at this middle point. This capacity current is then to be added vectorially to the previous load current and this new current value used to calculate the drop in the part of the line nearest the source of power. This drop is then vectorially added to the voltage at the center of the line to get the required power house voltage. The line current will always be greater at the power house than at the load end, but as all leading current, whether load current or that due to the capacity of the line produces a drop, the vectorial direction of which tends to counteract inductive drop, the voltage of the load and of the line may be either higher or lower than that of the power house end. This will depend on the power-factor of the load itself and on the capacity of the line and the frequency used. R.P.J.

583—Ammeter Reading on Pulsating Direct-Current—If in an alternating-current circuit an infinite resistance (open-circuit) be interposed in such a manner, as to obliterate the negative lobe in each cycle, what will be the significance of the reading of a direct-current ammeter in the circuit? What will be its relation to effective, average and maximum current values? H.H.

The current will be in effect a pulsating direct-current. If this current is to be used in connection with batteries or other similar applications depending upon its chemical effect, where average values instead of square root of mean square values of current are required, a permanent magnet type of meter will give directly a correct indication of the average value of current flowing, i.e., it will measure the average of the instantaneous values throughout the cycle including the zero values introduced for one-half of the cycle. For further information refer to No. 382 and article mentioned therein. P.M.

584—Protection Offered by Polyphase Overload and Reverse Current Relay—Please indicate by sketch a condition where a polyphase overload and reverse current relay operating from two series transformers would not give complete protection on a three-phase circuit. It seems that a short-circuit on any phase would cause at least one coil of the relay to operate. R.F.H.

We understand that by a polyphase relay is meant the type constructed

with two meter elements operated on the same shaft. Abnormal conditions such as short-circuits, grounds, etc., disturb the phase relations quite violently and very complex conditions result. The short-circuit current may be of very low power-factor. Assuming the case of a load of 50 percent power-factor, for example, one relay would not actuate if it were of the ordinary wattmeter type, and the other phase would not necessarily have sufficient power to close the contacts. A short-circuit across the phase to which the voltage coils of any type of overload and reverse current relay are connected, would have a totally different effect than a short-circuit across another pair of wires. It is preferable to use three single-phase relay elements with their voltage coils star-connected rather than one polyphase relay of the ordinary wattmeter or differential type, because of, first, the greater flexibility afforded and the greater ease with which repairs may be made if required; second, less chance of failure; third, the phase relations of the windings are correct instead of the currents being displaced 30 degrees from the respective voltages of the three phases at 100 percent power-factor as in the case of the connections necessary for the polyphase relays mentioned. P.M.

585—Special Relay Protection and Metering Connections—How can separate relay protection be obtained for a four-wire, two-phase and a three-wire, three-phase circuit from

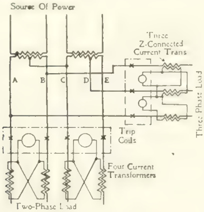


FIG. 585 (a)

the same secondaries of a single bank of two transformers, with standard four and three-pole circuit breakers having two trip coils each, so that a short-circuit or ground on any of the lines of either circuit would automatically trip the breakers. Also, how should one standard polyphase wattmeter be connected on the secondary side of the transformers to get an accurate record of the output of both two-phase and three-phase circuits. J.S.J.

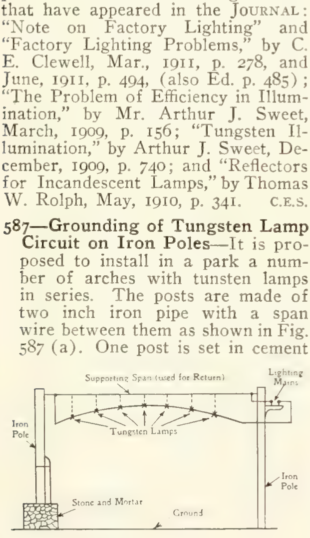
Complete overload protection is possible with the method of connection given in Fig. 585 (a), the series transformers on the three-phase circuit being Z-connected. (See Nos. 97 and 530.) The load cannot be measured by one wattmeter on the secondary side. Two meters are required, one for the two-phase and the other for the three-phase power. Total power can be measured by means of a single polyphase meter connected on the primary side of the transformer bank. P.M.

586—Method of Lighting Forge Shop—Please specify approximate method of satisfactorily lighting a forge shop 515 feet long by 100 feet wide. What method should be employed for determining the light for general illumination purposes? A.T.A.

It has been found that, in general, power in the proportion of three-fourths to one and one-fourth watts per square foot floor area is required for proper illumination. In the case in question, six rows by thirty of 250 watt tungsten lamps mounted 18 feet above the floor, with intensive type reflectors, would give good illumination. Experience has shown that it is economy to provide proper and sufficient illumination for factory employees. We believe that if cost of power, lighting installation, interest and depreciation be balanced against increased efficiency of the shop when properly illuminated, it will be found that to economize on light does not pay. In fact, the difference in cost of good illumination and bad illumination is a small fraction of one percent of the pay-roll. It is, of course, difficult to state just how much the efficiency of a man is increased by good illumination since a personal element enters largely into the question, but it will not be hard to convince the most skeptical

along this line if an opportunity be given to compare two departments, one provided with good illumination and the other with poor illumination. It is advisable to provide sufficient general illumination and eliminate, as far as possible, all local lighting and drop lights. Better results are obtained with lamps hung high, where they will not come within the line of vision. The tungsten lamps and focusing type reflectors are to be recommended. Placing the light units high will not materially affect the efficiency of the installation and the general results will be far superior. Note the following articles that have appeared in the JOURNAL: "Note on Factory Lighting" and "Factory Lighting Problems," by C. E. Clewell, Mar., 1911, p. 278, and June, 1911, p. 494, (also Ed. p. 485); "The Problem of Efficiency in Illumination," by Mr. Arthur J. Sweet, March, 1909, p. 156; "Tungsten Illumination," by Arthur J. Sweet, December, 1909, p. 740; and "Reflectors for Incandescent Lamps," by Thomas W. Rolph, May, 1910, p. 341. C.E.S.

587—Grounding of Tungsten Lamp Circuit on Iron Poles—It is proposed to install in a park a number of arches with tunsten lamps in series. The posts are made of two inch iron pipe with a span wire between them as shown in Fig. 587 (a). One post is set in cement



FIR. 587 (a)

in the stone and mortar base of an iron railing to which it is clamped and the other is set in the earth. The circuit wires can be run on only one side as shown. The voltage will be either 100 or 200. It is proposed to use the span wire for the return of the series of lamps and not insulate it from the posts. Would there be any possible danger of the railing and posts attaining a potential above ground? Would they become dangerous in case the wires of the tungsten lamp circuit were to come into accidental contact with a 2000-volt primary circuit through falling wires or breakdown of insulation between primary and secondary of one of the transformers? I believe that as long as the posts remained thoroughly grounded and the connections between them and the span wires perfect, it would be preferable to use the grounded span wire for return, but in case the ground connection of the poles became impaired there would be trouble. Would you advise insulating the return span wire from the posts? W.C.M.

We would recommend that the return span wire be insulated from the post. This is far better practice; particularly so with such low voltage and where it is a comparatively easy matter to insert a strain insulator between the post and wire, such, for example, as is used ordinarily for trolley circuits. We note that there is a possibility that the cement base of the post may prevent an effective ground connection and under these conditions the proposed arrangement would be dangerous, especially in case the tungsten circuit were to become crossed with a higher voltage circuit. C.E.S.

588—Automobile Magneto—Please explain the theory of the Splitdorf or Remy magneto and the connections thereof as used in the automobile. G.H.S.

Both the Splitdorf and the Remy magnetos are primarily of the low-tension type, but are operated in connection with a high-tension distributer. The former generates low-tension alternating-current in an armature of the "H" or Siemens type, this current passing through the magneto interrupter to the low-tension winding of an ordinary "jump-spark" automobile induction coil, from which the usual vibrating contact or "vibrator" is omitted. One end of the high-tension winding of this coil goes to ground and the other to a central high-tension terminal on the distributer which latter is incorporated with the magneto and which distributes the high-ten-

sion impulses from the coil to each of the respective engine cylinders in proper succession. The time of sparking in each cylinder can be varied as usual by shifting the angular position of one element of the interrupter by means of the "advance" lever of the automobile. The Remy Magneto connections are identical with the above, but the magneto is of the low-tension "inductor" type, with the winding stationary. For cross-sectional views of both magnetos see *Automobile* for Jan. 13th, 1910. J.L.A.,JR.

589—Testing Integrating Meter on Balanced Three-Phase Circuit—What method is used in testing the accuracy of a five ampere, 55-volt, two-wire integrating wattmeter used with a "Y" box and two current transformers but tested without the "Y" box on a three-phase balanced, delta-connected circuit? The current transformers are located in the two outside lines of the circuit. They are of 40 watts capacity and ratio 40 to 1. The potential ratio of the transformers used for the "Y" connection is 60 to 1. What is the constant used in testing? Please give vector diagram showing the voltages and currents in the various circuits? W.E.K.

It is assumed from the description of the meters that they were purchased as five ampere, 50-volt meters and, therefore, that the constants marked on the disc give the watt-hours per revolution when used without the transformers. The meters accordingly should be tested on full-load at five amperes and 50 volts, i.e., 250 watts, and on light load at about ten watts or less, comparing the revolutions of the disc with a rotating standard or timing them with a stop watch, in which latter case it would be necessary to hold the current exactly correct throughout the duration of the test by means of a standard instrument of precision. The power measured by the meter can now be calculated by use of the formula, $\text{Watts} = \frac{3600 \times K \times R}{S}$ where $R =$ No. of revolutions, $S =$ No. of seconds required to make this number of revolutions. $K =$ a constant, and $3\,600 =$ No. of seconds in one hour. By comparing the watts obtained by the formula with the actual watts measured by the standard, the accuracy of the meter may be checked. As a "Y" box is used with only two series transformers the readings of the two meters will give two-thirds of the power transmitted when multiplied by the meter transformer constants, i.e., 60:1 and 40:1. The phase relations may be seen from the vector diagram, Fig. 589 (a), in which, OA represents the phase position of the current in line A and therefore in the series coil of one meter, OC represents the relative phase position of the current in line C and therefore in the series coil of the second meter, OB represents the relative phase position of the voltage on the transformer connected across lines A and B, and OC that of the voltage on the transformer connected across lines BC. The "Y" box gives a neutral in the secondary circuits which is then represented by point O, Fig. 589 (a), and OA will then represent the relative phase position of the voltage on the first meter and OC the relative phase position of the voltage on the second meter. A.W.C.

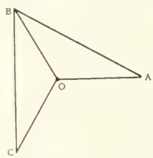


FIG. 589 (a)

590—Starting Air Compressor Motor—Why are the series wound motors on air compressors used in air brake equipments started without a rheostat? C. H.

Starting resistance is probably omitted in order to avoid complications. The operating characteristics of motors of sizes within the limits required for the above service (approximately three to seven hp) are such that no difficulty is ordinarily experienced in obtaining satisfactory operation by starting and stopping the motor by means of a line switch. N. W. S.

THE
ELECTRIC JOURNAL

Vol. VIII AUGUST, 1911 No. 8

The Chicago A. I. E. E. Convention

The annual convention of the American Institute of Electrical Engineers for 1911 was unique in more than one particular. In the first place the attendance far exceeded that of any previous Institute convention. The registration fell only a little short of one thousand, practically double the highest previous record. However, this convention was not noted for numbers alone. It also established a record to be proud of in the matter of solid information contained in the contributed papers and in the activity and interest displayed in the discussions.

The chief interest undoubtedly centered around the railway and the high tension transmission papers. Mr. B. F. Wood of the Pennsylvania Railroad, contributed a paper of rare value on behalf of the railway committee. The definite record of construction and operation of an important electric railway which is contained in Mr. Wood's paper is exactly the kind of information that makes the Transactions of the Institute more valuable for reference. Also the submission of Mr. Murray's paper for further discussion brought forth some exceedingly valuable contributions from well known railroad men. Of special note was the frank and vigorous comment on the Chicago railroad electrification situation by Mr. L. C. Fritch, from the railroad man's viewpoint.

Of no less interest was the discussion centering around the high tension transmission committee's program. One of the inherent disadvantages of any public discussion of high tension subjects when compared to private conversation is that in the former case an operator will never tell of his troubles while he may do so in private conversation. Now it is patent that the troubles of one high tension operator may be of inestimable value to another operator to the end that they may be avoided. Mr. Percy H. Thomas, the efficient chairman of the high tension transmission committee, is to be congratulated in that, although he has not gone so far as to induce operators to tell all of their troubles *per se,* he has induced quite a number of them to tell the remedies for some of the troubles

they have experienced in the past. This is an achievement and adds much to the value of the Institute Proceedings.

Of the telephone meeting in Chicago, it was said that it was the largest meeting to discuss telephones ever held by the Institute, not excluding some of the regular New York meetings held for the sole purpose of discussing telephones.

A city such as Chicago has some advantages as a convention city owing to the many excursions of educational value to the membership that may be arranged during the convention period. The visit to the Western Electric Works, as well as the large power stations of the Commonwealth Edison Company were not only enjoyable but instructive to the membership. However, in such excursions the matter of numbers, which is of advantage so far as discussions and enthusiasm are concerned, may become a distinct disadvantage. The trip to Gary was an illustration of this wherein the large number of visitors prevented the close inspection of machinery and other apparatus, which is really essential in order to make a trip of this kind of the instructive value which really belongs to it.

Another development in connection with this convention is the getting together of the section delegates and the consequent closer knitting together of various geographical sections which have become so prominent a part of the Institute in recent years. It is significant of progress when the representatives of the various sections can get together in harmonious conference such as the last convention witnessed. All told, the convention was one of which Retiring President Jackson should justly be proud.

P. M. Lincoln

Graduate Student Courses

With the broadening of the activities of the large electrical manufacturing companies has come the need of specialization in all departments. Salesmen no longer cover a company's whole line of product but handle only one class of apparatus, the same is true of the works force and of the designers. In the article on "Adapting Technical Graduates to the Industries," Messrs. Scott and Dooley tell how this specialization is combined with a more general training in a shop course for young graduate engineers. Instead of the "sink or swim" system of many years ago, under which only the best men obtained much benefit, the present method gives a

thorough training to a large number of men, and both selects and fits them for the work for which they are individually best suited. Thus in the end, considered both from the standpoint of the company and that of the young engineer, the present day course does the most good for the greatest number.

It is noteworthy that while the Westinghouse Company has for more than twenty years continuously maintained a course where young graduate engineers are trained, and while radical changes have been made in the course from time to time, there has never been a time when the management has even contemplated doing away with the students' course. On the one hand, the company has found that it is always in need of "graduate students" to fill positions in the engineering, works, erecting, and commercial departments. On the other hand, the young engineers are given a thorough, practical training which makes them better men for the company or other interests with which they may later elect to work.

H. D. Shute

Alternating-Current Generator Capacities

The outputs which may be secured by the various types of alternating-current armature windings and methods of connection are outlined in a comprehensive manner by Mr. Lamme, in this issue of the Journal. Beginning with an elementary sketch of a ring winding he explains in an easy step-by-step method the results secured by the different combinations and their relative advantages. The average electrical operating man understands in a general way that there are certain limitations to the output of generators which determine their capacities. Some of these ideas are based on actual observation and others are more or less distinct recollections of having read statements regarding particular cases. Numerous textbooks give certain data showing the variation in capacities of machines with different types of windings. Many of these comparisons are quite general and apply to machines of older types.

The introduction of turbine-driven generators, however, has so revolutionized the mechanical arrangement of the component parts of alternators that statements, which applied to older machines of the rotating armature type, no longer hold true. In these older and smaller machines the armature winding was distributed over the core so that the various coils were comparatively close together. In

large turbo-generators one coil may be so far separated from its neighbors that it could be roasted out by an over-load without causing undue heating of the adjacent coils. For this reason, while it was formerly sufficient to consider only the total copper loss as limiting the current in the windings, it is now necessary to rate generators so that the current in any one coil will not cause a temperature in excess of the maximum allowable. Thus when using a modern three-phase winding to deliver single-phase current it is not safe to assume that the total copper loss is an indication of the allowable output.

It is quite commonly assumed that the ratio of single-phase to three-phase armature capacities is 71 percent, but, even in those cases in which this value is correct, it is on the basis of equal total copper loss. On modern machines, however, the correct ratio is more often about 58 percent on the basis of maximum current in any armature conductor.

The true star three-phase winding is the one almost universally used for modern alternating-current generators, although the windings are occasionally connected in delta in order to secure desired voltages. However, the possibility of circulating currents in windings of this type limits the use of delta connections to special cases. Even for single-phase railway service, three-phase generators are used as there is almost always a certain amount of power delivered three-phase, and in addition the extra phase provides an emergency winding at little additional expense.

Two-phase generators were formerly much more common than at present. As they are now rarely built, the younger generation wonders why they were ever introduced. Mr. Lamme explains by stating that in the earlier days the single-phase rating was of prime importance and that by the use of a two-phase winding a high single-phase capacity could be secured to supply two separate single-phase circuits which did not interfere with each other as was the case in a Y-connected machine. He also shows that by making certain special connections to a three-phase winding unusually high single-phase ratings may be secured, but that they are of no particular value as the windings to which they apply are seldom used.

Since the capacity of a generator operating six-phase is greater than for three-phase the natural question is, "Why not use a large number of phases and get still better results?" Even with a very large number of phases the increase in rating amounts only to a little

over four percent, so that the increased complication incident to a multiplicity of phases is decidedly not worth while.

The whole article is enlightening by virtue of the clear and complete statements of the various possible combinations and as showing the engineering reasons which have led to the general use of certain windings to the exclusion of other types. It also brings out the fact that there are often opposing advantages which may lead to the rejection of a certain winding for one purpose whereas it may be permissible for other applications. A. H. McIntire

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Application of Pure Science in Industries

Apropos of the relation of pure science to its industrial application, the following remarks by Dr. S. W. Stratton, Director of the National Bureau of Standards, in a recent talk relative to the work of the Bureau, is of interest:—

"My training happened to be along the lines of mechanical engineering and later I became interested in physics. One of the things that impressed me most in my work in physics was the inertia, if I may call it such, of the application of pure science in our industries, the time that elapsed between the discovery of a principle and its application. I was continually brought in touch with facts that might be used to advantage in the different kinds of manufacturing with which I was reasonably familiar. When the opportunity came to take charge of and organize the Bureau of Standards, I saw at once the means for bringing about better conditions in this respect by making the Bureau a sort of clearing-house for certain kinds of scientific konwledge—a place where those engaged in the industries could go for the latest data regarding the properties of materials, the best methods of measurement and standards. The Bureau of Standards has come to be such an institution."

The Bureau should be a very potent factor in hastening the application of new discoveries and inventions, possessing as it does a splendid equipment in apparatus and trained men capable of determining the limitations and means of measurement of new phenomena, in a manner not possible with the more limited equipment of the average commercial institution.

The considerable time which may elapse between the discovery of a principle and its application finds an example in the dynamo. This year marks the fiftieth anniversary of the construction by Pacinotti of the first commercial type of dynamo. Twenty years

elapsed before the originality and merits of the invention were publicly recognized. An armature with symmetrically grouped coils connected to the bars of a commutator was re-invented by Gramme and given to the industrial world in 1870. The invention which lay dormant for so many years is the basis for the modern electrical machinery which has made electricity useful for lighting and power.

The inertia in applying scientific discoveries and inventions is often due not only to lack of knowledge of just what they are and what they involve, but also to the difficulty in perfecting a new device and in making a proper and efficient application. Invention must often be followed by painstaking and costly experimental development before a useful appliance results. Sometimes its useful application requires modification of the things to which it relates or charges in methods which are difficult to bring about.

The effort necessary to embody discoveries or ideas in practical form is also followed by somewhat similar difficulties in securing the adoption and general use of new things. These difficulties are:—first, a lack of information as to just what the new thing is; and second, the problem of adaptation to existing conditions, or a modification of these conditions which will enable the new device to be efficiently used.

The mere invention of a new and cheap method of making aluminum had to be followed by the development of processes for manufacture on a large scale. When the metal was available on the market, its characteristics had to be made known and its adaptation to various uses had to be made by methods different from those common with other metals. It had a field of its own which had to be developed.

The invention of the Tesla motor did not immediately supply alternating-current power service. Not only did the motor require experimental development but the high frequency, single-phase circuits which were then commercial, were unsuited to the polyphase motor. Even when generator, circuits and motors were ready for service, there remained the education of the public as to what the motor could do, and the needed changes in industrial methods which are required or which may bring improved operation when motors are used.

The discovery of metallic tungsten and the determination of its properties did not make a lamp. Great difficulties in the development of a process of making a filament had to be overcome and new methods of lamp making had to be worked out. New methods of

applying lamps, new reflecting devices, and new methods of illumination were all involved, together with the education of experts and of common people in the new system, before the new lamp could be generally and efficient applied.

There is necessarily a long and tedious road between the scientific discovery and its general application and use, yet there never has been a time when scientific discoveries were so quickly applied and when new appliances and methods were so readily adopted as they are being at present. This is due, in a large measure, to the increased facilities for the interchange of information and the spreading of general knowledge. In the electrical field the education of the public is one of the most important factors in the larger and more general use of electricity. The manufacturers of apparatus and the central station interests are recognizing this and broadening their policies. A public service corporation has a larger service to perform than the mere readiness to serve those who apply for electric power. It should serve the community by showing the benefits and advantages which electricity can supply. Both on the narrower commercial ground of self-interest and upon the broader basis of the advancement of the public welfare, it is the function of those who supply apparatus and electricity to educate the public in its use.

All the steps from the initial discovery to the ultimate utilization involve the application of scientific and engineering principles. This application is being made by men who understand these principles and who have the facility for applying and using them. The demand for such men is constantly increasing. Even in the commercial field the installation of electric lamps and of electric motors, which a few years ago received no particular consideration, is now directed in a scientific way by illuminating engineers and application engineers with the gratifying results which usually follow the intelligent application of scientific principles to common things. To overcome the inertia in the application of pure science in the industries and in the adoption of new devices in general service requires men well grounded in science, trained in its application and endowed with a goodly measure of level headed commonsense. It is this larger demand which is consuming the output of our technical schools and, in turn, the influence of these men is accelerating the development and adoption of the new appliances and new methods which are such an increasingly important factor in our transportation, our industries and our daily life.

CHAS. F. SCOTT

COMPARATIVE CAPACITIES OF ALTERNATORS
FOR POLYPHASE AND SINGLE-PHASE CURRENTS

B. G. LAMME

THERE are a number of popular misconceptions regarding the relative polyphase and single-phase capacities which can be obtained from a given winding. For instance, there appears to be a half-formed opinion that a given winding connected for two-phase service will give a slightly less output than when connected for three-phase; but, on the other hand, it seems to be generally assumed that the various three-phase windings all give the same rating.

Also, it is a widespread idea that when any polyphase machine carries a single-phase load the permissible rating, with the same temperature, is approximately 71 percent of the polyphase rating. While there are a few cases where this may be true, yet, in general, it is far from being the fact. This fallacy regarding single-phase ratings arose partly from early practice with polyphase machines, which were often designed to carry single-phase load almost exclusively, the polyphase load being a possible future development. In consequence, the type of armature winding chosen was, in many cases, that which gave a high single-phase output, with some sacrifice in the polyphase rating, and the single-phase rating in many cases was a relatively large percent of the polyphase rating simply because the polyphase rating was less than could have been obtained with a different type of winding.

The 71 (or 70.71) percent ratio of single-phase to polyphase ratings in a given armature arose partly from the fact that at these relative loads the total armature losses were practically equal. On machines of old design in many cases it could safely be assumed that with equal armature losses the temperature of the armature parts would be practically equal. This assumption does not hold, in general, on machines of modern design in which each individual part is proportioned for a specified result. The distribution of the armature losses is just as important as the total losses. If the temperature drop between the inside of the armature coil and the armature core is small compared with the temperature drop from the core to the air, then the temperature of the armature, or its rating, will depend largely upon its total losses, equal ventilation being assumed in all such comparisons. If, however, the temperature drop

from the coil to the iron, or from the inside of the coil to the outside, is relatively high, then the temperature limit may be fixed by the loss in an individual coil rather than by the total loss. This is particularly the case in high voltage machines where there is a considerable amount of insulation over the individual armature coils. Also, in many of the machines of later design (especially turbo-generators) each armature coil is practically separated from all other coils, so that one coil can have but little direct influence on the temperature of neighboring coils. In such an armature it is possible to completely roast out an individual coil or group of coils without seriously heating other coils or groups of coils. It is obvious that in such a machine the loss in the individual coils is what fixes the rating of the machine, and not the armature loss as a whole. It is evident, therefore, that when a polyphase machine, with such a winding, is loaded single phase, the maximum current which can be carried in any single coil must be the same for either polyphase or single-phase rating. As this type of winding is used in the majority of large capacity machines of the present day, the following comparison will show the relative rating of such machines on polyphase and single-phase loading. Three-phase ratings will be considered first, because the great majority of modern machines are wound for three phase.

THREE-PHASE WINDINGS

All the various types of commercial three-phase windings with their current and voltage relations can be derived in a very simple manner from the consideration of a ring armature with its windings arranged in six symmetrical groups, each covering 60 degrees of the ring, which may all be closed together to form the ordinary closed winding, or which may be separated into either three or six groups and connected to form various delta and star types of windings.

Let Fig. 1 represent such a ring armature closed on itself and with six taps brought out, designated as *A, a, B, b, C, c*.

By connecting together the points *Aa, aB, Bb,* etc., as shown in Fig. 2, a six-sided figure is obtained, which represents the various voltage and phase relations which can be obtained with all commercial three-phase (and six-phase) windings. It will be noted that *Aa* and *bC* are of equal length and are parallel in direction. The length represents e.m.f. and the direction represents phase relation. Therefore, these two groups are of equal e.m.f.'s and of the same

phase. The same holds true of *aB* and *Cc,* and of *Bb* and *cA.* These groups have also been numbered consecutively from 1 to 6, in Fig. 3, so that a given group can be identified by number. This

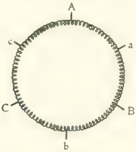


FIG. 1

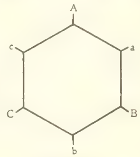


FIG. 2

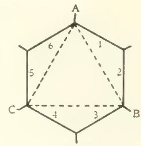


FIG. 3

figure is the same as Fig. 2 with three leads carried out from *A*, *B* and *C,* to form the three terminals of a three-phase winding. The dotted lines from *A* to *B*, *B* to *C,* and *C* to *A* represent the voltage and phase relations obtained from this combination. This is a closed

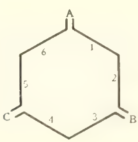


FIG. 4

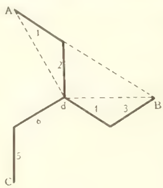


FIG. 5

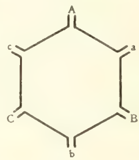


FIG. 6

coil winding and is the standard arrangement of winding on a three-phase rotary converter.

By opening the closed arrangement of Fig. 2 at the points *A, B* and *C,* as shown in Fig. 4, an open coil arrangement is obtained and the three parts resulting can be recombined in several ways, keeping

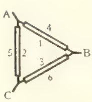


FIG. 7

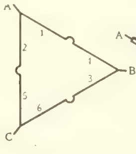


FIG 8

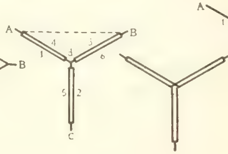


FIG. 9

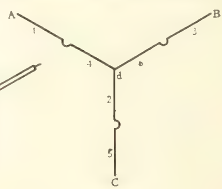


FIG. 10

the same voltage and phase relations of the individual parts. However, only one of these combinations, that shown in Fig. 5, has been used to any extent. This is one form of star winding which is sometimes used to give certain voltage combinations, as will be explained later.

By splitting Fig. 2 at six points instead of three, as shown in Fig. 6, various other open coil combinations of windings can be obtained while keeping each group or leg in its proper phase and voltage relations. One of these combinations is shown in Fig. 7, in which the groups which are similar in e.m.f. and phase are connected in parallel and the three resulting combinations are connected to form a delta winding. In Fig. 8 the two groups of similar phase are shown in series instead of parallel and connected to form a delta. Obviously Figs. 7 and 8 are equivalent, except that the terminal e.m.f. of one is double that of the other. By reconnecting the three components of Fig. 7 in the manner shown in Fig. 9, a parallel-star winding is obtained. Two arrangements are shown, one with all the groups connected together at the middle point, and the other with the two stars not connected at the middle. Fig. 10 is equivalent to Fig. 9, except that the two e.m.f.'s of equal phase are in series instead of in parallel, thus giving just twice the voltage of Fig. 9.

SIX-PHASE WINDINGS

The foregoing covers all of the usual combinations for three-phase windings, open and closed coil types. The same general scheme may be used to illustrate the six-phase combinations of windings which are frequently used in connection with rotary converters. In Fig. 3, a three-phase winding is shown with terminals at *A, B* and *C*. If three other terminals be formed by *a, b* and *c,* a second three-phase winding is obtained. The dotted lines in Fig. 11 illustrate the voltage and phase relations of these two windings. This is the so-called double delta arrangement, the dotted lines representing the voltage and phase relations of the transformers which supply the rotary converters. It is evident that the voltage represented by *ac* is equal in value and phase to that represented by *BC*. Therefore, one transformer with two secondaries of equal value could be tapped across these two circuits. Similar statements can be applied to the relations of the other phases in this diagram. In Fig. 2 it is evident that, if six terminals are used, a voltage can be obtained across *Ab, aC* and *Bc*. These three voltages are equal in value but have the 60-degree relation to each other. It is evident, therefore, that these transformers connected to a three-phase circuit can have their secondaries connected to this winding across the indi-

cated points. This arrangement is indicated in Fig. 12, and is the so-called diametral connection of six-phase rotaries. The middle points of the transformer winding from these three circuits can be connected together, if desired.

RELATIVE E.M.F. OBTAINED FROM THE FOREGOING COMBINATIONS

From an inspection of the above diagrams, and the application of but very little mathematics, all the e.m.f. relations of these various combinations can readily be obtained. In the following comparisons the magnetic field is assumed to be of such distribution that the e.m.f. waves will be of sine shape, as this greatly simplifies the various relations.

Let E represent the effective e.m.f. of any one of the six groups in Fig. 2. Then, combining the various groups geometrically, taking into account the angular relations, the various e.m.f.'s can readily be derived. The results are as follows:—In Fig. 3, the e.m.f. across

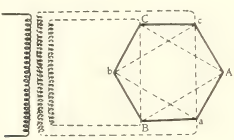


FIG. 11

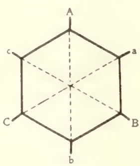


FIG. 12

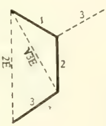


FIG. 13

AB, BC, etc., $= \sqrt{3} \times \mathrm{E} = 1.732\,\mathrm{E}$. In Fig. 5 the e.m.f. Ad is the same as AB in Fig. 3 and is therefore equal to $\sqrt{3} \times \mathrm{E}$, but the e.m.f. AB in Fig. 5 is equal to $\sqrt{3} \times Ad$. Therefore, the e.m.f. of $AB = \sqrt{3} \times \sqrt{3} \times \mathrm{E} = 3\mathrm{E}$. In Fig. 7, AB is evidently equal to one group or side of Fig. 2 and therefore the e.m.f. of $\mathrm{AB} = \mathrm{E}$. In the same way the e.m.f. of Fig. $8 = 2\mathrm{E}$. In Fig. 9 the e.m.f. Ad is evidently equal to E and the e.m.f. $AB = \sqrt{3} \times$ e.m.f. of Ad. Therefore the e.m.f. of $AB = \sqrt{3} \times \mathrm{E} = 1.732$ E, or same as Fig. 3. In the same way the e.m.f. of AB in Fig. $10 = 2\sqrt{3}\,\mathrm{E} = 3.464\,\mathrm{E}$. For the six-phase combinations the following e.m.f.'s are obtained: In Fig. 11 each of the deltas is the same as in Fig. 3 and therefore the e.m.f.'s are the same and are equal to 1.732 E. In Fig. 12, Ab is geometrically equal to twice aB and the e.m.f. Ab is therefore equal to 2E.

THREE-PHASE CAPACITIES

It might be assumed from casual inspection that all of the different three-phase and six-phase combinations would give the same capacities when carrying the same limiting current per armature coil. This, however, is not correct, as will be shown by the following:—

Let A equal the limiting current which can be carried by one coil or by one group of windings. This is not necessarily the current per terminal, but it is the current permissible in an individual coil without exceeding a certain prescribed temperature. Then the following ratings are obtainable with the above combinations of windings:—In Fig. 3 the rating $= 3A \times \sqrt{3} \times E = 5.196$ AE. In Fig. 5 the current per coil and per terminal $=$ A. The rating becomes $A \times \sqrt{3} \times 3E = 5.196$ AE. Therefore, the three-phase ratings of the windings in Figs. 3 and 5 are equal. In Fig. 7 the current in each phase of the delta is 2A, as there are two groups in parallel, each carrying current A. As the e.m.f. across terminals is E, the rating becomes $3 \times 2A \times E = 6$ AE. In Fig. 8 the current per side of the delta is equal to A and the e.m.f. is 2E. The capacity therefore becomes the same as for Fig. 7 or $= 6$ AE. In Fig. 9 the current per terminal is 2A as there are two groups in parallel for each terminal. The e.m.f. across the terminals is $\sqrt{3} \times E$. The capacity is therefore $2A \sqrt{3} \times \sqrt{3} E = 6$ AE. The rating of Fig. 10 is also 6 AE, the same as 9.

In Figs. 11 and 12 the ratings can be determined by direct inspection from the following method of considering the problem.

In a closed coil polyphase machine, such as shown in Fig. 11, one circuit can be taken off from A and a, a second circuit from a and B, etc., and the total number of circuits which can be taken off corresponds to the number of armature taps. Each circuit can be considered as having its own rating. Therefore, the effective voltage of each of such circuits times the current per circuit, times the number of circuits, equals the rating. In Figs. 11 and 12 six circuits can be taken off, each with voltage E, and carrying current A. The rating therefore becomes 6 AE. The same method could be applied to any other number of phases from closed coil windings.

It is evident from the foregoing that the same rating cannot be obtained from the armature winding with all methods of connection. In those three-phase arrangements in which two groups of similar phase relations are thrown in series or parallel, the highest output is

obtained. In those cases where two e.m.f.'s out of phase with each other are combined to form one phase of the three-phase circuit, the resultant e.m.f. is at once reduced by such combinations and the capacity of the machine is therefore reduced, simply because the most effective use of the windings is not obtained. The three-phase closed coil winding is therefore not as effective as the true delta or star type of winding. For this reason the closed coil winding is used only in those cases where some condition other than the current capacity itself is of greater importance. Otherwise, delta and star windings are always used, the star being preferred, as it gives a higher voltage with a given number of conductors, or a smaller number of conductors for a given voltage, and is therefore somewhat more effective in the amount of copper which can be gotten into a given space.

SINGLE-PHASE CAPACITIES.

Any three-phase machine with one of the above windings can be used to carry single-phase load by using two of the three terminals. The single-phase e.m.f.'s obtained will therefore be the same, in each case, as the three-phase. The current capacity per coil, or group, on single phase can be no greater than on three phase. On this basis, therefore, the following single-phase ratings are obtained with the above combinations:—*A* and *B*, Fig. 3, as the single-phase terminals, with the limiting current A per coil, the windings *1* and *2*, will carry current A, and *3*, *4*, *5* and *6* will carry 0.5*A*. The total current at the terminals will therefore be 1.5A, and the e.m.f. per terminal will be $\sqrt{3}$ E. The single-phase rating then becomes $1.5\,A \times \sqrt{3}\,E = 2.598\,AE$. The corresponding three-phase rating is 5.196 AE. The single-phase rating is therefore just 50 percent of the three-phase for this combination. In Fig. 5, the current per phase is A, while the e.m.f. is 3E. The single-phase rating therefore becomes 3 AE. The corresponding polyphase rating is 5.196 AE. The single-phase rating is therefore 57.7 percent of the polyphase rating. In Fig. 7 the total current in two groups is 2A, while in the other four groups of the delta the total current is A. The total current at the terminals therefore becomes 3A. The e.m.f. is E and therefore the single-phase rating becomes 3 AE. The corresponding three-phase rating is 6 AE. The single-phase rating is therefore 50 percent of the polyphase for a true delta winding. The same holds true for Fig. 8. In Fig. 9 the current per group is A and with two groups in parallel the current per terminal is 2A.

The e.m.f. across the terminals is $\sqrt{3}$ E. The single-phase rating therefore becomes $2A \times \sqrt{3}$ E or 3.464 AE. The three-phase rating for the same combination is 6AE. The single-phase rating therefore becomes 57.7 percent of the three-phase when a true star winding is used. Fig. 10 gives the same results as Fig. 9.

It may be noted that in the three-phase star arrangement two groups are carrying all of the current, while the third is idle and could be omitted. This means that the active winding covers two-thirds of the armature surface, while an idle space of one-third the surface lies in the middle of the winding. In the delta winding one group, covering one-third the surface, is directly in phase with the single-phase e.m.f. and is therefore in its most effective position. The other two carry current also, but are relatively ineffective, as the e.m.f.'s generated are displaced 60 degrees in phase from the single-phase e.m.f. delivered. With the delta arrangement, therefore, two-thirds of the winding acts in an ineffective manner and one-third is very effective. In the star arrangement, two-thirds of the winding is almost in phase with the terminal e.m.f. (being 86.6 percent effective) while one group is entirely idle. The star arrangement is thus about 15 percent more effective than the delta arrangement.

The single-phase rating which can be obtained from the two six-phase combinations, shown in Figs. 11 and 12, should also be considered. In either of these cases, if two opposite terminals, such as *Ab*, be taken as the single-phase terminals, then the e.m.f. will be 2E. As each half of the winding can carry the current A, the total current which can be handled is 2A. The single-phase rating, therefore becomes 4AE. The corresponding polyphase rating is 6AE. The single-phase rating is therefore 66.7 percent of the polyphase, or is higher than in any of the other three-phase combinations shown. While this combination gives the highest single-phase and polyphase ratings, yet if three phase is used on the transmission circuit, transformers must be interposed.

The high single-phase rating obtained in this case is due to the fact that the arrangement is equivalent to the star arrangement with the idle phase added, as illustrated in Fig. 13. The addition of this extra phase increases the terminal e.m.f. in the ratio of 100 : 86.6, while the current per terminal remains the same. This arrangement, when used for both single-phase and three-phase, implies the use of a closed coil type of winding which, as shown before,

cannot give the maximum three-phase rating unless six terminals are used.

It should be noted that the three groups shown in Fig. 13 have the same phase relations as a delta winding when used on single-phase; that is, one of the three groups is in phase with the terminal voltage, while the other two have a 60 degree relation. However, these two groups carry the full current A; while in the delta arrangement they carry one-half current. Therefore, although the voltage relations are the same, the current relations are quite different; which accounts for the increased capacity with the groups connected as in Fig. 13 or Fig. 12.

Fig. 13, like Fig. 12, is equivalent to covering the entire armature surface with copper which is equally active in carrying current when the machine is operated single-phase. However, compared with the three-phase star arrangement where two groups only are active, it may be seen that the voltage and the output have been increased in the ratio of 100:86.6, or about 15 percent, by the addition of 33 percent in copper, and 33 percent in total armature copper loss. It is evident, therefore, that the addition of a third group when operating single-phase does not give results in proportion to the material used.

COMPARISON OF SINGLE-PHASE AND THREE-PHASE RATINGS ON THE BASIS OF EQUAL TOTAL ARMATURE COPPER LOSS

All the foregoing comparisons have been on the basis of equal losses in a given coil or group; but it has been shown that with some of the windings, when operated on single-phase, the currents are not divided equally. In such cases the total copper loss in the windings must be less than where the current is divided equally. In the following comparisons the total copper losses for three-phase and single-phase are given, and the possible increase in single-phase rating for the same total copper loss is indicated.

In Fig. 3, for three-phase, $6A^2r =$ the armature copper loss, where $r =$ the resistance of one group and $A =$ the limiting current per group. For single-phase $\left(\frac{A^2}{2}\right) \times 4r + A^2 \times 2R = 3A^2r =$ total armature copper loss. The three-phase loss is therefore twice the single-phase on the basis of equal limiting current. For equal total loss the single-phase current could therefore be increased as the $\sqrt{2}$, since the loss varies as the square of the current. As the

former single-phase output was 50 percent of the three-phase, then for equal losses the single-phase output becomes $50 \times \sqrt{2} = 70.7$ percent of the corresponding polyphase rating.

In Fig. 5, the three-phase loss $= 6A^2r$. The single-phase loss with the same limiting current $= 4A^2r$, as there are but four groups in circuit instead of six, each group carrying the same current as when operating three-phase. The three-phase loss is thus 1.5 the single-phase, and for equal losses the single-phase current can be increased in the ratio of $\sqrt{1.5}$. The former single-phase rating was 57.7 percent. This, therefore, can be increased to $57.7 \times \sqrt{1.5} = 70.7$ percent of the corresponding three-phase rating.

In Figs. 7 and 8, the three-phase loss $= 6A^2r$. The single-phase loss $= 3A^2r$, as determined by direct inspection of currents and resistance. For equal losses, therefore, the single-phase current can be increased as the $\sqrt{2}$. The output then becomes $50 \times \sqrt{2} = 70.7$ percent of the corresponding three-phase rating.

In Figs. 9 and 10, the three-phase loss $= 6A^2r$. Single-phase loss $= 4A^2r$. The single-phase output $= 57.7$ percent and for equal loss this can be increased in the ratio of $\sqrt{1.5}$. The output then becomes 70.7 percent of the corresponding three-phase output.

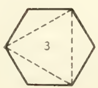
In Fig. 12, the six-phase loss $= 6A^2r$. The single-phase loss $= 6A^2r$, as all the groups carry equal currents and all are in circuit. Therefore the single-phase current cannot be further increased and the single-phase output remains at 66.7 percent of the six-phase output (or three-phase beyond the transformers).

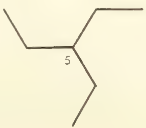
From the above it would appear that for single-phase operation most of the above windings would give, for equal armature copper loss, 70.7 percent of the three-phase rating. However, it should be taken into account that the three-phase ratings are not all equal on the basis of equal copper loss. In Figs. 3 and 5, for instance, the three-phase rating is equal to 5.196 AE, or 86.6 percent of the three-phase rating of 6 AE with the arrangement shown in Figs. 7, 8, 9 and 10. The single-phase ratings of Figs. 3 and 5, therefore, are 70.7 percent of 86.6 percent, or 61.2 percent of the best three-phase rating which can be obtained. Therefore, on the basis of 6AE being the best three-phase output, then with equal copper loss, the arrangements in Figs. 3 and 5 give $61.2 \times 6AE = 3.792AE$ as the single-phase rating with equal copper loss, while Figs. 7, 8, 9

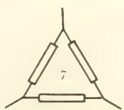
TABLE I—SHOWING RELATIVE CAPACITIES OF VARIOUS TYPES OF WINDINGS

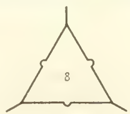
Type of Winding	E.M.F. Across Terminals		Capacity, with Limiting Amperes A, Per Coil				Armature Copper Loss with Amps. A Resist. r. Per Group		Armature Copper Loss, 1-Phase and 3-Phase Equal			
	Three-Phase	One-Phase	Three-Phase	One-Phase	Ratio 1-Ph. to Cor'd'g 3-Ph. Percent	Ratio 1-Ph. to Best 3-Ph. Percent	3-Ph.	1-Ph.	Amperes A_1	Capacity with Amperes A_1	Increase in Copper Loss in Coils Carrying Current A_1—Percent	Ratio — 1-Ph. Capacity to Best 3-Ph.—Percent
Fig. 3	$\sqrt{3}$ E $=1.732$E	1.732E	$3A\times\sqrt{3}$E $=5.196$AE	$1.5A\times\sqrt{3}$E $=2.598$AE	50	43.3	$6A^2r$	$3A^2r$	$\sqrt{2}$ A $=1.414$A	$\sqrt{2}\times1.5\sqrt{3}$AE $=3.675$AE	100	61.2
Fig. 5	3E	3E	$\sqrt{3}A\times3$E $=5.196$AE	$A\times3$E $=3$AE	57.7	50	$6A^2r$	$4A^2r$	$\sqrt{1.5}$ A $=1.225$A	1.225×3AE $=3.675$AE	50	61.2
Figs. 7 and 8	E 2E	E 2E	$2A\times3\times$E $=6$AE $A\times3\times2$E $=6$AE	$1.5\times2A\times$E $=3$AE $1.5\times A\times2$E $=3$AE	50	50	$6A^2r$	$3A^2r$	$\sqrt{2}$ A $=1.414$A	$\sqrt{2}\times3$AE $=4.242$AE	100	70.7
Figs. 9 and 10	$\sqrt{3}$ E $=1.732$E $2\sqrt{3}$ E $=3.464$E	1.732E 3.464E	$2\sqrt{3}A\times\sqrt{3}$ E $=6$AE $\sqrt{3}A\times2\sqrt{3}$ E $=6$AE	$2A\times\sqrt{3}$ E $=3.464$AE $A\times2\sqrt{3}$E $=3.464$AE	57.7	57.7	$6A^2r$	$4A^2r$	$\sqrt{1.5}$ A $=1.225$A	$1.225\times2\sqrt{3}$AE $=4.242$AE	50	70.7
Fig 12	2E	2E	6AE	$2A\times2$E $=4$AE	66.7	66.7	$6A^2r$	$6A^2r$	A	4AE	0	66.7

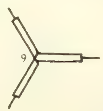
A_1 = maximum current per coil with single-phase connection to give same copper loss as in three-phase connection.

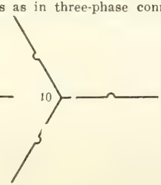


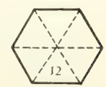












and 10 give 4.243AE as the single-phase ratings with equal copper loss, and Fig. 12 gives 4AE as the single-phase rating with the same copper loss. Therefore, the arrangements in Figs. 7, 8, 9 and 10 are better than any of the others for single-phase rating, if total copper loss is the limit rather than the loss in an individual coil or group.

However, if total copper loss is the limit, then there is still a difference between the true delta and star windings. With the delta winding the current A is increased 41 percent ($\sqrt{2}A$) which means that one of the groups will have double the copper loss which it has on three-phase, while with the star winding the current A will be increased slightly over 22 percent ($\sqrt{1.5}\ A$) which means that two groups of the winding will have their copper losses increased 50 percent. With the star arrangement, even with the same copper loss, the coils are not worked so hard on single phase as with the delta arrangement.

The above relationships are summarized in Table I.

TWO-PHASE WINDINGS

The two-phase windings may be analyzed in a manner similar to the preceding. Assuming a ring, as in Fig. 14, with four taps brought out 90 degrees apart and assuming that this winding is the same as that in Fig. 1, then the following e.m.f.'s and capacities are obtained:—

Fig. 15 represents a closed coil two-phase winding corresponding to the three-phase winding in Fig. 3. Calling E_1 the e.m.f. of each group, the e.m.f.'s AC and $BD = \sqrt{2} \times E_1$. By opening Fig. 15 at two opposite points, as in Fig. 16, the two parts may be rearranged to give Fig. 17. This is an interconnected open coil two-phase winding; that is, the central points are connected together so that there are fixed e.m.f. relations between all four terminals. The e.m.f. Ad is equal to E_1, and the e.m.f. across AB, BC, etc. $= \sqrt{2}\,E_1$, while the e.m.f. across AC and $BD = 2\,E_1$. By splitting the winding in Fig. 16 at four points, the arrangement shown in Figs. 18 and 19 are obtained. These two windings are equivalent, except that in Fig. 18 the two groups which are in phase are connected in parallel, while in Fig. 19 they are series. If the middle points in Fig. 19 are connected together the arrangement becomes equivalent to Fig. 17. In Fig. 18, e.m.f.'s AC and BD are equal to

E_1, while there is no fixed e.m.f. relation between *AB, BC,* etc. In Fig. 19 the e.m.f.'s *AC* and *BD* are equal to $2E_1$ and there is no fixed relation between *AB, BC,* etc.

In Figs. 20 and 21 the usual two-phase three-wire arrangement is shown. In Fig. 20 $AB = E_1$ and $AC = \sqrt{2} \times E_1$. In Fig. 21 $AB = 2E_1$ and $AC = 2 \times \sqrt{2}\, E_1$.

Capacities of Two-Phase Windings—Let A equal the current per coil, this current being the same as for the three-phase winding.

FIG. 14

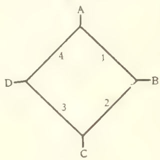


FIG. 15

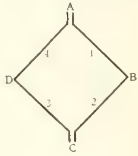


FIG. 16

Then, for all of the commonly used windings shown in Figs. 15, 17, 18, 19, 20 and 21, the capacity equals $4AE_1$.

COMPARISON OF TWO-PHASE WITH THREE-PHASE CAPACITIES

As the same winding has been assumed for both two-phase and three-phase, it is of interest to compare their ratings. Comparing E and E_1 in Fig. 22, it may be seen that $E_1 = \sqrt{2} \times E$. Therefore, the two-phase capacities given above, when put in terms of

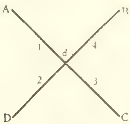


FIG. 17

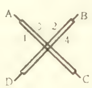


FIG. 18

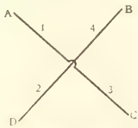


FIG. 19

three-phase e.m.f.'s become, in all cases, $4A \times \sqrt{2} \times E = 5.656$ AE. As already indicated, the three-phase closed coil capacity $= 5.196$ AE; the closed coil six-phase capacity $= 6$ AE; the open coil (star or delta) three-phase capacity $= 6$ AE. Therefore, the three-phase closed coil arrangement gives the least output, while the two-phase, (which is, in reality, four-phase with a closed coil winding) gives somewhat better results and the six-phase closed coil gives still better results.

SINGLE-PHASE RATING FROM TWO-PHASE WINDING

Two of the terminals of the two-phase windings may be used for single-phase. Assuming the same current A per coil as in two-phase or three-phase, then the single-phase capacity becomes,—in Fig. $15 = 2A \times \sqrt{2}\, E_1 = 2.828\ AE_1$; in Fig. $17 = A \times 2E_1 = 2\ AE_1$; in Figs. 18 and $19 = 2\ AE_1$; in Figs. 20 and $21 = 2.828\ AE_1$.

Comparing the best single-phase obtained from the two-phase with the best single-phase from the three-phase windings, then $2.828\ E_1A = 4\ AE$, or the same as obtained from the six-phase closed coil winding.

Comparing the three-phase closed coil winding with the two-phase closed coil winding for both polyphase and single-phase ratings, the following is obtained on the basis of same loss per coil:—

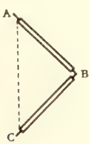


FIG. 20

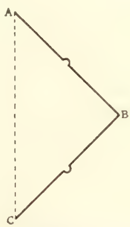


FIG. 21

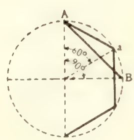


FIG. 22

The 3-phase closed coil winding gives 3-phase rating of 5.196 AE
" 3 " " " " " single " " " 2.598 AE
" 2 " " " " " 2 " " " 5.656 AE
" 2 " " " " " single " " " 4 AE

It is, therefore, apparent that with the closed coil winding the two-phase arrangement (or four-phase in reality) gives higher outputs, for both polyphase and single-phase, than the three-phase closed coil arrangement.

It may be of interest to note that in some of the earlier polyphase machines, when the single-phase rating of a polyphase generator was frequently of more importance than the polyphase rating, the closed coil two-phase winding was generally used. One reason for the selection of this type of winding was the high single-phase rating which could be obtained without undue sacrifice in the polyphase rating.

SPECIAL CONNECTIONS FOR SINGLE-PHASE

All of the preceding comparisons have had to do with symmetrical arrangement of windings. However, by putting on one or more additional connections, which are used for single-phase operation purely, the windings can sometimes be made to give larger single-phase ratings than where the straight polyphase connections are used for single-phase operation. Two such arrangements are shown below:—

It is shown in Fig. 12 that by taking off single-phase current at *Ab,* a high single-phase rating can be obtained. For supplying three-phase circuits, however, it was stated that transformers would have to be interposed to transform from six-phase to three-phase. However, by using *A* and *b* as the single-phase terminals and using *A, B* and *C* as three-phase terminals, thus having four terminals total on the winding, as shown in Fig. 23, the machine can supply

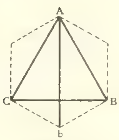


FIG. 23

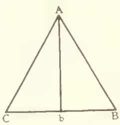


FIG. 24

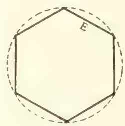


FIG. 25

three-phase directly to the circuit and can also deliver single-phase with the best utilization of winding. In this case the three-phase rating equals 5.196 AE and the single-phase rating equals 4 AE. The single-phase thus becomes approximately 77 percent of the polyphase. This high relative rating, however, is due to the fact that the three-phase rating is only 86.6 percent of the maximum three-phase which could be obtained.

In a similar manner, with the delta winding shown in Fig. 8, an improved single-phase rating can be obtained by putting an additional terminal at the middle of one of the phases, as shown in Fig. 24. Single-phase is then taken off at *A* and *b,* while *A, B* and *C* are the three-phase terminals. In this case two of the delta groups are nearly in phase with the single-phase, while the third is practically idle as far as voltage is concerned, although it carries the full current. If the e.m.f. of *AB* is 2E, then the e.m.f. of *Ab* is $\sqrt{3}$E. The total single-phase current is 2A. Therefore, the single-phase rating becomes 3.464 AE. The single-phase rating in this case is

therefore 57.7 percent of the three-phase, instead of 50 percent where the single-phase was taken off at the terminals *AB*. The above two arrangements are therefore more effective than the usual single-phase from the same types of windings. However, as will be shown later, the true delta and the closed coil three-phase windings are seldom used on alternating-current generators and therefore the above special arrangements are of no particular commercial advantage.

COMPARISON OF ALTERNATING AND DIRECT-CURRENT RATINGS FROM SAME ARMATURE WINDING

If direct current be taken from the same winding the limiting direct current per coil should be the same as the effective (or square root of the mean square) current when delivering alternating current. This is the value A used in the preceding comparisons. The direct-current e.m.f. is taken off from two opposite points of the armature. This e.m.f. therefore corresponds to the two opposite terminals of either the two-phase closed coil or six-phase closed coil winding shown in the preceding diagrams. The direct-current e.m.f. will be equal to the maximum or peak value of the alternating-current e.m.f. taken off from these two points. This will be $\sqrt{2}$ times the effective value used in the preceding comparison. For the six-phase diametral arrangement, it was shown that the effective alternating-current e.m.f. $= 2E$. Therefore the peak value or direct-current e.m.f. will be equal to $\sqrt{2} \times 2E$. As the limiting current is A, and as there are two direct-current branches, the total direct current will be 2A. The direct-current output therefore becomes $4 \times \sqrt{2}\, AE = 5.656\ AE$.

The following interesting comparisons can therefore be made:—

Direct-Current capacity	$=5.656$ AE	
1-Phase closed coil capacity,	$=4$ AE	$=70.7$ percent of D.C.
3-Phase " " "	$=5.192$ AE	$=91.8$ " " "
2 " (4-phase)" " "	$=5.656$ AE	$=100$ " " "
6 " " " "	$=6$ AE	$=106.1$ " " "
3 " open " "	$=6$ AE	$=106.1$ " " "

From the above it appears that the two-phase closed coil (and two-phase open coil) capacity is equal to the direct-current capacity from the same armature winding. The three-phase closed coil is less than the direct current, while the six-phase is greater than the direct current. The three-phase true star or delta winding and the six-phase closed coil winding are all slightly more effective than

when the same winding is used for direct-current.

The question may be raised whether still higher ratings could not be obtained from a given winding by taking off more phases. An examination will show that higher ratings can be obtained with the number of phases increased, with the closed coil winding; but it can also be shown that the possible increase over the six-phase arrangement is very small. An easy way of comparing the ratings of closed coil windings, with different numbers of phases, is to compare the number of circuits which can be taken off between adjacent taps or terminals all around the winding. This is equivalent to comparing the perimeters of the polygonal figures shown in the diagrams for the various closed coil combinations and is illustrated in Figs. 25, 26, 27 and 28. In Fig. 25, calling one side E, then the perimeter $= 6$ E. In Fig. 26 the perimeter is $4\sqrt{2}\,E = 5.656$ E. In Fig. 27 the perimeter $= 3 \times \sqrt{3}\,E = 5.196$ E. In Fig. 28, which represents single-phase, the two sides of the polygon coincide, making a straight line. Therefore, double the length of this line should

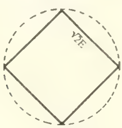


FIG. 26

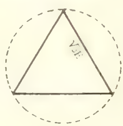


FIG. 27

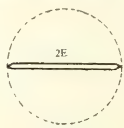


FIG. 28

represent the perimeter, which $= 4$E. A comparison of these values shows that they are exactly in proportion to the alternating-current capacities given above.

It is evident that the greater the number of phases obtained from the closed coil winding, the more nearly the perimeter of the polygon approaches the circumference of the circle. With an infinite number of phases a true circle would be obtained and in this case the perimeter becomes $2\pi E = 6.283$ E. Therefore, the maximum possible polyphase rating is $6.283 \div 6 = 1.047$, or 4.7 percent greater than the six-phase closed coil rating or the true star and delta rating. Also, the greatest possible polyphase rating is greater than the direct-current rating in the proportion of 6.283 : 5.656, or approximately 11 percent.

FIELD HEATING

In the above comparisons of the relative ratings of the three-phase, two-phase and single-phase windings, the armature copper

losses only have been taken into account; but if the problem is to be considered in its completeness, other armature conditions and the field conditions must also be taken into account. A comparison of the three-phase and two-phase ratings shows that they are usually so close together that the field conditions would probably not exert a controlling influence on the relative capacities. In general, it may be taken that those combinations of polyphase windings which give lower ratings at the same time give lower armature reactions.

In comparing single-phase with polyphase ratings, however, the field conditions, both as regards the field winding and field core, must be taken into account. The armature reaction of the single-phase winding is pulsating and tends to produce magnetic disturbances in the field poles or core which may result in very considerable iron losses, both eddy and hysteretic. In general, these disturbances are relatively much greater on larger capacity machines, so that provision must be made on such machines for suppressing or avoiding the effects of the armature reaction. This can be accomplished to some extent, by completely laminating the field poles. Another method which has been used on very large machines is the employment of heavy cage dampers in the pole faces. These dampers must have current capacity such that when developing ampere-turns sufficient to completely neutralize the armature pulsations, the heating effect in the damper winding, due to the current in it, is relatively low.

Field copper heating, in most cases, is not a controlling condition, owing to the fact that the single-phase rating, defined by the armature heating, as indicated above, is so much lower than the polyphase rating that the field current is usually somewhat less than on the polyphase loading. This is particularly true when the rating is fixed by the heating of individual armature coils. However, if the single-phase rating is determined by the total armature loss and not by the loss in individual coils, the permissible armature capacity on single-phase may be such that in some instances the field current is larger than on polyphase. In such cases, if the field copper is the limiting condition, the single-phase rating cannot be as high as the armature would permit. It may be assumed, however, that in large machines the armature conditions, as fixed by the loss in individual coils, determine the safe single-phase rating; and under this assumption the field conditions, except in regard to the use of dampers or the elimination of the effects of armature reaction, need not be considered.

APPLICATION OF VARIOUS TYPES OF ALTERNATING-CURRENT WINDINGS

The three-phase true star type of winding is the one which, in general, lends itself to best advantage to the various types of alternating-current machinery. It may be a question then as to why any other types of windings are used. Where windings other than the true star winding are used there is usually some condition which is more important than the output. In the following will be given some of the principal applications of the different types of windings.

Closed Coil Types—The closed coil type of winding is always used with rotary converters. The controlling feature in this case is that the rotary converter carries a commutator, which naturally requires a closed coil type of winding. Rotary converters are, in practice, wound for three-phase, four-phase (usually known as two-phase), and six-phase; and the number of collector rings is 3, 4 and 6 respectively. The three-phase winding is generally used in small capacity converters. While the three-phase winding allows less output than the four-phase or six-phase, on small converters the capacity is usually not limited by the armature copper loss, while the use of three rings somewhat simplifies the machines.

Four-phase converters are used to a very considerable extent in connection with two-phase circuits. However, where the supply circuit is three-phase it is rare that the transformation is from three-phase on the supply circuit to the two-phase on the converter, as there are certain disadvantages in such transformation which more than offset the slight advantage of the four-phase converter over the three-phase. Moreover, where a higher number of phases is of advantage in a rotary converter, it is practicable to transform from the three-phase supply circuit to six-phase for the converter. Two arrangements of such six-phase transformation are in use, as illustrated in Figs. 11 and 12. One of these is the so-called "Double Delta" arrangement, in which each of the step-down transformer circuits is equipped with two secondaries, as indicated in Fig. 11. These are connected to form two separate deltas, one being inverted with respect to the other. The other arrangement is the so-called "Diametral" arrangement, as shown in Fig. 12. This has advantage over the double delta in that only one secondary circuit is required for each phase and the middle points of these secondary circuits may be connected together for a neutral or middle wire between the direct-current leads from the rotary converter.

In a rotary converter the armature copper loss is generally so

small, compared with that of the straight direct-current or straight alternating-current machine with the same winding, that all considerations of the comparative heating of three-phase, four-phase and six-phase windings, as on alternating-current generators, has practically no bearing on the rotary converting rating. In a rotary converter, an increase in the number of phases over six represents a considerable reduction in the armature copper loss,—much more so than in the closed coil alternating-current generator. This is due, in the rotary converter, to the fact that one armature winding carries both the direct and the alternating currents, which are to a certain extent, flowing oppositely.

Closed coil windings are also occasionally used on the secondaries of induction motors in order to give a better choice in the number of slots than would be allowed otherwise. Such windings when used on induction motors are usually of the two-circuit or series type, for the purpose of increasing the voltage as much as possible and at the same time keeping the number of conductors small, while retaining the closed coil arrangement. A two-circuit closed coil winding will close upon itself symmetrically if the number of turns or coils is one more or less than a multiple of the number of pairs of poles. This sometimes allows the use in the secondary of an induction motor of a number of coils or slots which has no close numerical relation to the number of primary slots. For instance, if the primary of a four-pole induction motor has 48 slots with an open coil, star or delta winding, then with 39 coils and slots in the secondary, a symmetrical closed coil three-phase winding could be obtained, while if an open coil secondary were used the number of slots should preferably be 36 or 42, which might not be as desirable as 39 in some cases. This simply illustrates an occasional use of the closed coil winding. Such windings were at one time used very extensively on low voltage, rotating armature, two-phase generators. Such generators were very satisfactory for delivering a relatively large percentage of their rating single-phase. Furthermore, with one conductor per slot and with bolted-on end connectors, the potential between adjacent end connectors was at all points relatively low. The symmetrical arrangement of such windings also rendered them very suitable for use with supporting bands or end bells over the end winding. However, with the advent of the rotating field machines, and particularly with the use of higher voltages, the open coil star winding has entirely superseded the closed coil type of generator winding.

Three-Phase Star Windings—Two types of star windings have been shown, namely, those in Figs. 5 and 10. That of Fig. 5 gives less output than that of Fig. 10 in the ratio of 86.6: 100. There would appear, therefore, to be no use for the Fig. 5 arrangement; but, in certain cases, in using a given winding it may be desired to reduce the voltage from 12 to 15 percent while retaining normal conditions otherwise. In such a case the lower voltage could be obtained, if a new winding were used, by simply chording the winding one-third the pitch. On the other hand, if an existing winding is to be used, the same result could be obtained by coupling, as in Fig. 5.

In induction motors the arrangement shown in Fig. 5 may be used occasionally where the windings are arranged for coupling for two different speeds. In some cases this type of winding may give better average field distribution for the two numbers of poles than the one shown in Fig. 10. In this case, therefore, it is the distribution of the magnetic field, and not the capacity of the winding, which is the important feature.

The arrangement shown in Fig. 10 is the true star winding which is used almost universally on three-phase machines. For a given voltage it requires fewer conductors than any other type of winding. This is of very material advantage in allowing a smaller number of conductors per slot, with a given number of slots, which, as a rule, allows a better utilization of the slot space, that is, more copper can be gotten into a given slot. Furthermore, in relatively high voltage machines where the conductors may be very large in number and small in size, the star winding with its smaller number of conductors, each of much larger size, gives more substantial coils than any other arrangement. Another advantage of the three-phase winding is its fairly good utilization of copper when operated on single-phase. When operated on purely single-phase load, one group of the star could, of course, be omitted, but if it is retained it becomes a reserve winding which may be used in case of an accident to one of the active groups of the winding. By opening any defective coil in an active group and connecting in the reserve group in place of the defective one, the machine can still develop its specified rating on single-phase.

Another advantage of the star type of winding is the readiness with which the central or neutral point can be grounded, which is a very considerable advantage in some high voltage systems.

Delta Type Windings—The true delta type winding, as illustrated in Figs. 7 and 8, is not used to any great extent in either alternating-current generators or induction motors. For a given voltage it requires 73 percent more conductors, each of 58 percent of the capacity of those of the true star type of winding. As the terminals of all three groups are connected in a closed circuit it is necessary that the e.m.f.'s generated in the three should balance each other at all instants or there is liable to be circulating current around the windings. This means that the winding must be applied only where the conditions are favorable, or the conditions in the design must be made to suit the type of winding. This winding is occasionally used on low voltage turbo-generators of fairly large capacity, due to the fact that the delta type winding requires more conductors than the star type. For example, in a large capacity two-pole turbo-generator, wound for relatively low voltage, the number of conductors for the star winding may be so small that a satisfactory number of slots is not obtained, even with only one conductor per slot and even using the double-star winding, shown in Fig. 9. In such case a double delta winding will allow 73 percent more conductors and slots than the double star will give. Also, each conductor will be much smaller than in the star arrangement, which may be of considerable advantage in the case of low voltages and very heavy current per conductor.

Delta windings are occasionally used on machines which are arranged for connections for two different voltages, such as 6 600 volts and 11 000 volts. If an armature is wound for star connection at 11 000 volts, then it can be coupled in delta for 6 600 volts with practically the same inductions, losses, field currents, etc. The delta type of winding is also used occasionally in the primaries of induction motors for special purposes, such as multi-speed combinations where the winding is changed from one number of poles to another. In general, however, the star type winding is used on induction motors. The delta winding is not well adapted for single-phase operation on account of its low capacity. Also, it does not admit of grounding of the neutral or central point of the system. Taking everything into account, the true delta winding is only used where some special condition is imposed upon the winding which puts the star arrangement at a disadvantage.

SINGLE-PHASE ALTERNATORS

All the foregoing comparisons have been made on the basis of

the same armature winding being used for three-phase, two-phase or single-phase. The relations shown do not hold true in general for machines which are wound initially for single-phase service, such as for single-phase railway or electro-chemical or electro-fusion work. In such cases the amount of armature copper used and its distribution are such that the armature coils, either individually or as a whole, do not determine the true limits of output; but the armature as a rule can carry any current that the field winding will stand, so that the field temperature becomes the true limit in such machines. Also, very massive, well distributed cage dampers are used with such machines when they are of large capacity and these, in turn, have a certain effect on the characteristics, such as the regulation, and thus have an influence on the permissible capacity. It is well known that if the inherent regulation of an alternator is made poorer, the capacity can usually be increased with the same limiting field temperature. In large single-phase generators, especially for railway service, the capacity is increased by sacrifice in the inherent regulation of the machine. However, the massive dampers greatly improve the regulation for quick changes in load; while the poorer inherent regulation only affects the regulation over considerable intervals of time and automatic regulators, acting on the alternator excitation, readily take care of the slow fluctuations. In consequence, single-phase generators of large capacities may be built for ratings which bear no definite relation to any of those given above.

The armature windings of single-phase generators, when arranged for single-phase purely, are frequently distributed over only part of the surface. Usually they cover considerably more than half the surface, and in extreme cases 80 percent or more. Of course, when spaced like a true three-phase winding they cover two-thirds the surface. This arrangement admits of an extra group being added to the winding, which is normally idle, if the winding is connected in star, this group being a reserve in case of accident, as mentioned before. However, when such a group is not added, the winding generally covers more than two-thirds the surface, rather than less, but rarely covers the whole surface.

THE CENTRAL STATION AND THE MANUFACTURER*

CHAS. F. SCOTT

COÖPERATION between the central station and the manufacturer of apparatus will be treated under three heads:—"Engineering," which will deal with the apparatus by which the central station produces and distributes its current; "Commercial Engineering," which will treat of the apparatus (such as motors, lamps, and heating appliances), and the methods for extending the use of central station service; and, "Commercial," which will deal with the common commercial interests of the central station and the manufacturer.

ENGINEERING

As good apparatus, well operated, is the engineering basis upon which the whole central station business rests, the question naturally arises as to how the central station can coöperate with the manufacturer to secure better apparatus.

Standard apparatus should be purchased if it will meet the requirements. The standard apparatus of to-day is the outcome of years of evolution in which the best thought of the designer, the best skill of the factory and the results of experience are combined. Patterns, dies, tools and the experience of the workmen all are available for the making of a standard product in less time and at less cost than a special or new one which has not had the test of experience in service. Hence the acceptance of standard types and sizes of generators and auxiliary apparatus will not only assist the manufacturer, but will, in the long run, bring to the central station better and cheaper apparatus.

Conference with the manufacturer before deciding upon a definite generating unit or other apparatus may be helpful in determining what standard apparatus will meet the requirements. The central station may secure the advice of the engineering department of the manufacturer which is necessarily in touch with the new and changing conditions and with the operating requirements of other stations. The wisdom of such a conference is obvious, yet it is not uncommon for rigid specifications to be presented without conference and without provision for alternative propositions.

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*A paper presented before the Canadian Electrical Association, Niagara Falls, Ontario, June, 1911. Condensed.

On the other hand, electric practice is continually developing. We must continually improve and progress. New conditions arise. To improve his apparatus, the designer should know just what it must do. He may surmise the conditions, and he may make laboratory tests, but these may not be the actual requirements and conditions of service. He needs the experience which the central station operator possesses. Lightning arresters, regulators, switches, circuit breakers and instruments are the outcome both of the laboratory and experience in actual service. Now the experience of the central station operator can greatly assist the manufacturer. To be effective, there must be freedom and frankness—not mystery and secrecy. If something is not satisfactory, if there is some weak point in the apparatus, if there is some new condition which is not met, little is gained by saying that the whole thing is a failure, while much may be gained by definite, intelligent information. Conditions are rapidly changing in central station designs and substantial engineering progress requires that the skill of the manufacturer and the experience of the operator be combined.

COMMERCIAL ENGINEERING

The growth of the off-peak load and of the power business is the most striking feature in central station activity at the present time. The application of electric power is first of all an engineering problem. A motor must be adapted in speed and power, and in mechanical connection, to the work which it is to do. But beyond these simple problems is the general problem of using to best advantage the power which the motor develops. It is the superior service which the motor gives, the convenience with which it can be operated, the better speed adjustment, the increased quantity or the improved quality of the output of the machine it drives, the simplicity of motor drive as compared with engines and shafting and belts, and the independence of one tool or one department from others when driven by separate motors, these and a score of other factors are indirect advantages which often become the really important things to be gained in using electric power.

The prospective user of electric power is often unfamiliar with the apparatus and the various engineering features involved in its application and operation, and he is ignorant or unconvinced of the advantages which will result from its commercial introduction. Hence it is that the large power loads of progressive central stations have been the result of a systematic educational campaign among

prospective customers. This is a field in which manufacturing company and central station can work together. The information and data which the progressive manufacturing company acquires in order to design its apparatus to meet the requirements of actual service are the precise data which the central station needs in order to understand and effectively present the situation to the power users which it should serve.

Electricity is usually an auxiliary factor. The cost of electric power is a small part of the total cost and yet it may contribute very largely to successful operation. For example, the cost of power in most industries is only three of four percent of the total cost of the product and the cost of lighting is less than one percent. Hence, it follows, obviously, that if greater and better output can be obtained from men or machines by an increase or an improvement in the power or lighting, then considerably greater expense for light or power is amply justified.

This may be illustrated by an example:—Assume as a convenient figure that the cost to the purchaser for a five horse-power motor is $100.00. Assume further that the annual charge for depreciation, interest and repairs is as much as $20.00 per year, or say $0.07 per day. In the daily cost of production, therefore the first cost of the motor appears as $0.07. The power taken by the motor is say two kw (corresponding to a load factor of 40 percent); hence, the power for the ten-hour day will be 20 kw-hrs. and, if the rate is, say, 2.5 cents per kw-hr., the cost will be 50 cents per day. If the motor drives a line shaft supplying power to five workmen at $2.00 per day, their wages will amount to $10.00 per day. The various overhead charges in the operation of machine tools is about one and one-half times the operators' pay.* This gives the overhead charge as one and one-half times the wages, or $15.00 per day.

The various items assumed in the total cost of production, all in connection with the five horse-power motor, are as follows:—

Cost of motor per day	$ 0.07
Cost of power per day	0.50
Cost of wages per day	10.00
Cost of overhead per day	15.00
Total cost per day	25.57
Total cost per hour	2.56
Total cost for twelve minutes	0.50
Total cost for one minute	0.04

*See "Notes on the Cost of Operating Machine Tools," A. G. Popcke, in the JOURNAL for December, 1909.

Let us analyze:—The cost of power is fifty cents in a total of \$25.57 per day, or only two percent of the total. Suppose that it be possible by using more power to increase the output slightly, note what will result. If the power used be increased one-tenth, making fifty-five cents instead of fifty cents per day, and this can increase the output by, say, five percent, then the production will be increased in value by five percent of \$25.57, or a little more than \$1.25. Hence, five cents more spent for power results in a net gain of \$1.20 under these conditions, or twenty-four times the cost of the additional power. These figures may be put in the following form:—

Assumed gain in production (five percent of \$25.57)....	\$1.25
Assumed additional cost of power (ten percent of \$0.50).	0.05
Net gain	\$1.20

Expressed in another way, the cost of power per day is fifty cents, which is equal to the total cost for 12 minutes; i. e., one can afford to pay twice as much for power if he could thereby gain more than 12 minutes per day. Hence, the problem is not to save power, but to use power effectively. The cost of power is so small an item in the present example that it can be even doubled if a gain in rate of production of more than two percent can be secured thereby.

The cost of the motor in the foregoing example is equivalent to \$0.07 per day, or approximately one-quarter of one percent of the total cost. Obviously, if some other motor equipment would give even one percent greater output, the value of which would be twenty-five cents per day, it would be economical to install it, even though it cost twice as much, i. e., even though the motor cost \$200 instead of \$100, or fourteen cents per day, instead of seven. In other words, the cost of the motor per day is less than the total cost for two minutes. Hence, if one motor equipment will save more than two minutes per day over another one, its purchase is justifiable even if the price were twice as great. If, therefore, one motor outfit can be more conveniently operated, if starting or stopping requires less time, if there is less interruption due to poor insulation or hot bearings or controller contacts, which amounts, on the average, to even one or two minutes a day, or to one hour a month, then it is well worth while to purchase the better outfit even at a very considerably increased cost.

In the departments of lighting and heating there is a similar situation and in general, the same arguments apply.

We are all apt to take too narrow a view; we fail to see that the really important thing is not the saving of a few cents in doing a thing by the old way, but in the large economies which come from new methods which electricity makes possible. Efficiency in operation and in management as well as in power plants and in machinery is now awakening interest and wide discussion. Electricity is the great modern means of securing efficiency in the applications and uses of power. The progressive men of manufacturing companies and of central stations are recognizing this and through their efforts it is beginning to impress itself upon the public. The problem is a tremendous one, its solution means much for the public, for the central station and for the manufacturer, and it merits united effort in its solution.

COMMERCIAL

In their commercial prosperity and success, as measured by the earning of dividends, the manufacturer and the central station have much in common. One supplies apparatus, the other operates it, and together they contribute to supply a growing need of the community. The central station is no longer a novelty supplying current within a radius of a mile or so to those who can afford the luxury of an incandescent lamp upon a combination fixture where the gas can be lighted when the current fails. Light is no longer a luxury. The company supplying light and power is now called a public service corporation. It is recognized, both practically and legally, as an institution which supplies a fundamental need by rendering a public service to the community. Government commissions see that the public is provided with an adequate service at fair rates and also that the company is protected against unjust competition and that it secures rates which are fair and adequate.

Moral and legal obligation, as well as good business policy, dictate that the central station should supply the best possible service and should extend that service in the public interest as well as its own interest. This means that the central station must provide a reliable and continuous service; that it must not merely be ready to supply current, but that it must also render a public service in showing how to use electricity and how and what direct and indirect gains follow from its use, and, further, it must develop in its equipment and in its organization to meet the larger field of service which

the universal use of central station power will make necessary. From the standpoint of the customer, reliability and continuity of service are of first consequence. These depend, first of all, upon the quality of the electrical apparatus which is used. As the first cost of this apparatus is insignificant compared with the cost of the power it uses and the value of the products which it aids to produce, quality and not price is of first importance in the installation of a motor. Whatever the central station can do to aid its customers in securing good motors; whatever it can do to support the manufacturer who makes good motors and to induce the making of still better motors, contributes to the best interests of all concerned. The central station and the manufacturer together, by educating the public to the use of electricity in the right way on a sound engineering basis with the best apparatus are laying the surest foundation for their commercial success.

To insure that the electrical progress of the next decade will keep pace with that in the past, the central station must meet the new demands for reliability and for a broad, comprehensive expansion of its activity and its policy. The central station should be the source of power for all purposes, for domestic uses, for industry and for transportation. Apparatus larger in output and better in quality will be demanded for generating, controlling and using electric power in all forms. The experimental investigation and the practical development of apparatus has been carried on in the past largely by the manufacturing companies. They have expended millions of dollars in developing new and better apparatus and the central station has reaped the direct benefit. Such work must go on, it must be aided both by engineering coöperation and by the commercial endorsement of the central station interests.

Electricity is bringing about a new power era, because it facilitates the generation, the transmission, the distribution and the universal application of power. The central station is the agency for supplying this power. Upon its progressive policy in acting with the manufacturer of apparatus on the one hand, and the public on the other, depends the commercial prosperity of manufacturer and of central station, and the general welfare of the community whose industries and transportation and daily life are becoming more and more dependent upon electric power.

ELECTRIC DRIVE FOR WATER WORKS IN RURAL DISTRICTS

H. W. SMITH

THE domain of the electric motor is continually expanding, but there are many cases in which the possibilities of electric power are still unrealized. It is the object of this article to point out some of the opportunities for the use of electric power in water works in small cities and rural districts. In the larger cities water is generally obtained from lakes or rivers, and filtration plants are then required to make it potable; but in small towns the water is commonly pumped from artesian wells, often 1 000 to 2 000 feet deep. The well piping extends through all surface formations and into the underlying rock stratum, thus excluding all possibility of contamination from surface seepage. The water is usually found in a sand or gravel stratum with a rock cap or wall above it. For raising the water to the surface, three main methods are employed:—

SYSTEMS OF PUMPING

1—*Deep Well Plunger Pumps,* either single or double acting, give a positive lift, and can be used for pumping from any depth. The single acting pump is least expensive to install, but delivers the smallest quantity of water from a given bore, of any of the commercial pumps and works at an efficiency of about 65 percent. The deep well double-acting pump delivers about 70 percent more water than can be raised with a single-acting cylinder of the same displacement, and develops an efficiency up to 75 percent.

2—*The Air Lift System* is used for raising water or oil from deep wells by means of compressed air. It consists of two properly proportioned pipes; the water pipe and the air pipe. The lower end of the water pipe is submerged in the water usually to a depth not less than half the lift, and the air pipe, which is usually smaller, delivers compressed air inside the water pipe a few feet short of its lower end. The rising column in the water pipe consists of air mingled with water. Since the pressure, caused by the weight of this column is less than the pressure of the surrounding water in the well, the water and air are forced up and out of the pipe. This method has many decided advantages over other systems, mainly because of the entire absence of valves, plunger rods and

other mechanism in the well. Muddy or gritty water or quicksand can be pumped as well as clear water. The yield of the well is increased and the water is ærated, purified and cooled by the expanding action of the air in contact with it in the well.

The air lift system is suitable for any depth of well and will raise more fluid from a drill hole of a given size than any other method of pumping, but obtains a lower efficiency than any other, the efficiency being from 15 to 30 percent. When wells are of extreme depth and very expensive to put down and a large quantity of water is required, it is often cheaper to install the air lift system and use a relatively greater amount of power than to bore more wells and install additional pumps of another type that can be operated more economically after the installation is made. Where the water needs to be ærated before it can be used there is this additional reason for using the air lift system.

3—*Deep Well Centrifugal Pumps*—Pumps of the multi-stage vertical shaft type are set in the wells and driven by long shafts extending to the surface. A vertical motor is coupled to each pump by means of a flexible coupling. At the surface are two ball bearings and beneath them a water step is usually placed to carry most of the weight. Water is admitted under pressure to the under side of the cap of this water step in such a way as to make it ride on a film of water. At intervals guide bearings are placed within the vertical shaft. The maintenance cost of this type of pump is high, but the increased efficiency over the air lift system counterbalances this. The deep well centrifugal pump can be used where the well is not less than 12 inches in diameter inside the well casing and when the lift does not greatly exceed 150 feet. This type of pump will elevate more water from a deep drill hole than any other type, except the air lift, and will develop an efficiency up to 60 percent.

The relative amounts of water delivered from a given well, considering the amount delivered by the single-acting cylinder pump as unity are:—Deep well, double acting, 1.7—2; turbine centrifugal, 3—4; air lift, 4—10.

For delivering the water into mains, stand pipe or reservoir, motor-driven centrifugal pumps or steam driven plunger pumps are generally used. In old installations pumps were generally driven by steam engines or gas engines and in the air lift system, the air compressors were steam driven. In many cases they have been changed over to electric drive and power bought from central sta-

tions with a saving in the cost of operation. The advantages of electric operation are several and may be enumerated briefly as follows:—1—First cost less; 2—Cost of operation less, owing to smaller buildings required, elimination of boilers, coal handling and ash hauling, no coal storage required, no firemen required, maintenance on motors less than on steam or gas engines; 3—Greater reliability.

TYPE OF MOTORS

Alternating current is now the standard source of supply and is very well adapted to pump work. Constant speed motors are generally used, of either the squirrel cage or slip ring type. The choice of the motor depends on the starting conditions and the size of the generating plant, slip ring motors being installed where the starting conditions are severe and where the effect of the starting of the motor on the power plant must be considered. Motors can be geared or belted to deep well plunger pumps, the former giving a more compact arrangement and the latter a more flexible connection. Compressors can be direct connected or belted to motors, the latter being the more common arrangement. Deep well centrifugal pumps are driven by direct-connected vertical motors with flexible couplings. Centrifugal pumps with horizontal shafts are direct connected by a flexible coupling to the motor, the usual arrangement in municipal plants being to connect a pump on either side of the motor. The pumps normally operate in parallel, but can be arranged for series connection to give high pressure for fire service.

EXAMPLES OF RESULTS OBTAINED

A short summary of the results now being obtained in several small pumping plants, which are operated by electric power, is given below:—

Plant A—This plant has one deep well, 10 inches in diameter for 100 feet, the balance being 8 inches in diameter, the total depth of the well being 1 400 feet. The lift varies from 50 to 100 feet and the discharge head is about 100 feet. The equipment consists of a 20 horse-power, 850 r.p.m. slip ring motor belted to a deep well, double-acting plunger pump, with a rated capacity of 200 gallons per minute. This plant has been operating for over three years without trouble of any kind, pumping about 100 000 gallons per day during winter months and 250 000 gallons in summer months. One

man operates this installation, with one assistant during the summer months on account of the longer hours. The average kilowatt-hours per million gallons pumped is 765.

Plant B—This pumping plant has two 1 000 foot wells. The air lift system is employed because the water is charged with sulphurous gases and needs to be ærated before it is drinkable. The amount of water pumped is 150 000 gallons per day in winter months and 300 000 gallons in the summer months, the lift being 68 feet. The equipment consists of two air compressors with 14 by 12 inch cylinders, giving an air pressure of 56 pounds, each belted to a 40 horse-power, 690 r.p.m. squirrel cage motor. One of these compressors is held in reserve. The water is discharged into a reservoir whose capacity is 74 000 gallons. From the reservoir a combination of four single-stage centrifugal pumps forces the water into the mains. Each pump is rated at 300 gallons per minute at 45 pounds head and is driven by a 20 horse-power 1 700 r.p.m. squirrel cage motor, as shown in Fig. 1. The piping is so arranged that any pump can be run separately, any two or three, or all four in parallel, any two in series delivering 300 gallons at 90 pounds pressure, or the four in series-parallel giving 600 gallons at 90 pounds pressure, the latter two combinations being used for fire

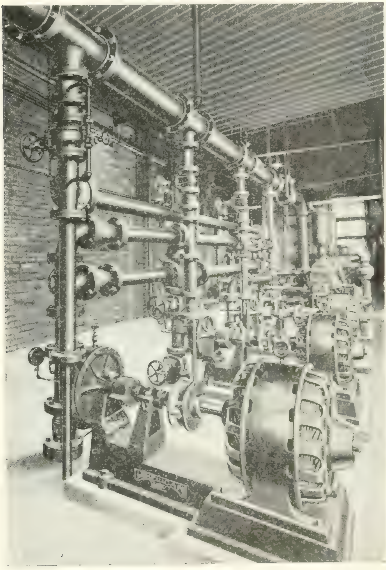

FIG 1—20 HORSE-POWER MOTORS DRIVING SINGLE-STAGE CENTRIFUGAL PUMPS. MOTOR DRIVEN AIR COMPRESSORS IN BACKGROUND

The piping is so arranged that the pumps can be connected in any combination of series and parallel.

service only. The average kilowatt-hours per million gallons pumped is approximately 2 500.

Plant C—This plant has a 1 400 foot well, the lift being 150 feet. There is an 80 000 gallon reservoir and a stand pipe of 100 000 gallons capacity. The amount of water pumped is 225 000 gallons per day in the winter and 300 000 gallons per day in the summer. The air lift system is used to raise the water to the surface. A 100 horse-power, 690 r.p.m. squirrel cage motor is belted to a two-stage air compressor, with cylinders 18 and 11 by 16 inches, running at 125 r.p.m. and delivering air at 105 pounds pressure. This compressor is operated about sixteen hours per day with an

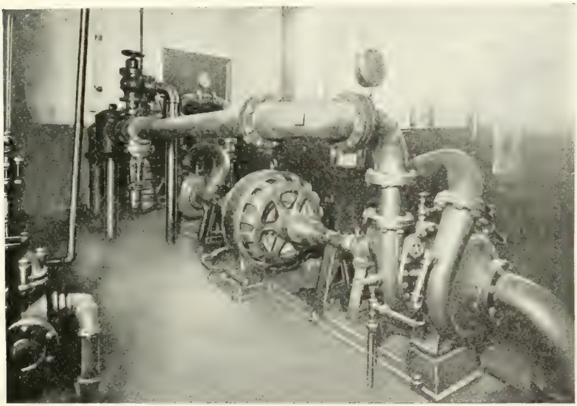

FIG. 2—100 HORSE-POWER MOTOR DRIVING COMBINATION CENTRIFUGAL PUMPS

average load on the compressor motor of about 94 horse-power. From the reservoir a triplex pump, with cylinders 7 by 8 inches, discharges the water into the mains. The pump is belted to a 20 horse-power, slip ring motor. There are three shifts, one man per shift. The average kilowatt-hours per million gallons pumped is approximately 6 000. The street lighting for the city is also run in conjunction with this pumping plant.

Plant D—This pumping plant uses the air lift system and centrifugal pumps. There is a total of eleven wells ranging from 1 500 to 2 100 feet in depth, the average lift being 150 feet. The amount of water pumped is 1 200 000 gallons per day in the winter

and 2 000 000 gallons per day in the summer. The equipment consists of a 200 horse-power, 580 r.p.m. squirrel cage motor belted to a two-stage air compressor with cylinders 13 and 22 by 16 inches, operating at 160 r.p.m. and delivering air at 105 pounds pressure. This pumps operates approximately seventeen hours per day. In addition, there are four centrifugal pumps, each with a capacity of 750 gallons per minute at 40 pounds pressure. They are placed one on each side of a motor, as shown in Fig. 2, each motor driving two pumps through a clutch coupling, so that any one pump can be disconnected. The motors are 100 horse-power, 1 120 r.p.m. of the slip ring type. This plant is operated with two shifts, one man per shift. The average kilowatt-hours per million gallons of water pumped is approximately 4 000.

Plant E—This plant uses deep well vertical shaft centrifugal pumps for raising the water to the surface and horizontal shaft centrifugal pumps for delivering the water into the mains. There are three wells, each 2 100 feet in depth. The diameter is 15 inches for the first 250 feet below the surface, and is then reduced by successive steps to ten, eight and six inches. In two of these wells are placed three-stage deep well centrifugal pumps, 13 inches in external diameter, located 80 feet below the surface with a 20 foot suction pipe on the end. These pumps are rated at 350 gallons per minute at 100 feet head, and are driven by 25 horse-power, 1 120 r.p.m. squirrel cage motors through long vertical shafts, extending to the surface. The water is lifted through an eight inch pipe in which are placed guide bearings for the vertical shaft at intervals of eight feet. The shaft consists of 16 foot lengths, coupled together. The third well has a similar but larger equipment, the pump being rated at 1 000 gallons per minute at 100 feet head and driven by a 75 horse-power, 1 700 r.p.m. motor.

The reservoir has a capacity of 550 000 gallons and the stand pipe has an additional capacity of 275 000 gallons. For pumping into the mains there are two centrifugal units; one consisting of a 50 horse-power, 1 120 r.p.m., squirrel cage motor with a centrifugal pump on either side, the capacity of the unit being 900 gallons at 50 pounds pressure, the other consisting of a 100 horse-power, 1 120 r.p.m., slip ring motor with two centrifugal pumps, delivering 2 000 gallons per minute with 50 pounds pressure. The consumption per million gallons of water pumped at this plant is approximately 800 kilowatt-hours.

METHODS OF OPERATING HYDRO-EXTRACTORS

ALBERT WALTON

IN textile mills where yarn or cloth is washed or dyed it is necessary to dry the goods before subsequent handling in the other processes. This is usually accomplished in two stages. In the first stage the bulk of the liquid is removed by centrifugal action and in the second the material is completely dried by a slow heating and fanning system. The removal of most of the liquid is usually accomplished by means of a "hydro-extractor" which is essentially a basket, from 24 to 72 inches in diameter, generally of perforated copper, mounted on a vertical spindle which is arranged to be rotated at high speed. Into the basket are packed the wet skeins of yarn or pieces of cloth to the amount of several hundred pounds. It is then rotated about its vertical axis, coming gradually up to a speed of from 750 to 1 000 revolutions per minute. During the first part of the acceleration the skeins or pieces rearrange themselves and start to pack tightly against the walls of the basket. Great care has to be taken to see that none of the goods projects beyond the basket where it can be whipped against projections or strike the operatives standing nearby, as the momentum of the loaded basket is very considerable and a great deal of damage might be caused before the machine could be brought to rest. A friction brake is usually provided to stop the machine to avoid unnecessary loss of time after the drying is completed.

It is very desirable to be able to predetermine the amount of moisture that will be left in the goods so that the speed of the hot air machine may be regulated for maximum results and deliver perfectly dry material without consuming more time than necessary. As the amount of drying done in the hydro-extractor depends almost wholly on the speed and the time of drying and as the time can be made perfectly definite it is evident that the feature of a fixed speed of operation is of importance. With the time of acceleration and running speed fixed, a very definite amount of drying can be accomplished and repeated time after time by duplicating the duration of the cycles of operation.

The driving of hydro-extractors presents a problem peculiar to itself. The load is intermittent and irregular. To start the loaded basket and accelerate it to its full speed in the brief interval desired, involves a heavy draft of power, while little effort is required to run it at constant operating speed, after it has reached that point. The demands of production require a quick acceleration

and it is important that this be obtained as this period of the cycle of operation is in a measure lost time. The length of time full speed is maintained varies in different installations, but it is usually under ten minutes and most frequently about five.

There are three well recognized methods of applying the power—by steam engine, by belt and by electric motor. The steam drive has some points of advantage, principally, however, in the starting qualities, but there are many serious drawbacks. The engines are extremely wasteful and inefficient and require costly piping from boiler room to dye house, and the very necessity for providing this piping frequently makes it impossible to locate the extractor at the most desirable point with reference to other machines. More important, however, is the consideration of speed

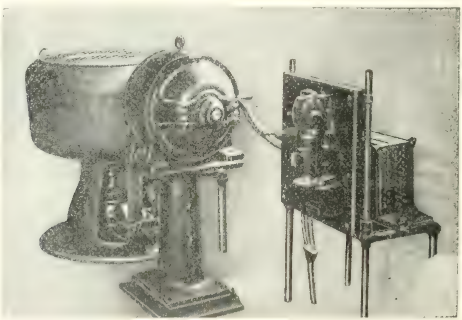

FIG. I—DIRECT-CURRENT MOTOR AND AUTOMATIC CONTROLLER, DRIVING HYDRO-EXTRACTOR

regulation. With the throttle wide open the speed of operation varies over wide limits depending on the steam pressure, the amount of the load and the way the material is packed in the basket. As the drying effect varies as the square of the speed it is entirely impossible to predetermine the amount of moisture that will be left in the goods. The engines, furthermore, are usually small and cheaply made, and operated by ignorant unmechanical men. It is rare to find an engine that has been operating on one of these machines for any length of time that is not pounding badly and leaking steam with every stroke. Where the engine is mounted above the basket, driving directly to the spindle, there is the added disadvantage of splashing oil and oil-laden water. The engine drive therefore has some advantages in starting but is wasteful of power, inefficient in

drying, expensive to pipe, noisy, leaky and dirty, not to mention being dangerously hot.

Another method of operation is by belt from shafting. The basket is started by shifting the belt from a loose to a tight pulley. It is obvious that for the period of acceleration, approximately two minutes, the belt must slip badly either at the main pulley, the counter-shaft pulley, the tight pulley of the extractor or the spindle pulley. It is usually divided between the last two points. At first the operative slides the belt on an inch or so, letting the slip occur at the tight pulley, causing burning and damage to one edge of the driving belt. He then gives his attention to stowing away the goods in the basket to prevent ends and loops from flying out as the speed slowly increases. As soon as this is accomplished he shifts the belt all the way on and the slipping then occurs at the small spindle pulley until the maximum speed is reached. For this reason it is difficult to keep this belt in good condition as it is short and tight, and rapidly deteriorates under such service. This kind of drive, therefore, has the advantage of simplicity and fairly constant operating speed but the disadvantage of slow starting and high up-keep of belts. The machine must be located near the main shafting and here is involved also the further disadvantage of imposing heavy intermittent peak loads which reflect back to all the other machines driven from the same shafting as momentary checks in speed.

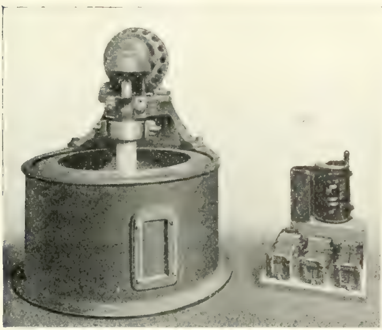

FIG. 2—WOUND SECONDARY INDUCTION MOTOR WITH DRUM CONTROLLER, DRIVING HYDRO-EXTRACTOR

The third and best system is the use of a proper electric drive. A great many drives have been used for this purpose with varying degrees of success. Direct-current motors have been used successfully for this purpose for some years, but with alternating-current motors the problem has not proven so simple. On the early installations squirrel-cage motors were used, but two difficulties were

encountered which made the drive unsatisfactory. If a standard motor of the proper horse-power to run the machine was used, the period of acceleration was so long and the starting so frequent that the rotor became overheated. If, on the other hand, a motor large enough to avoid excessive heating were installed the starting torque was so great that the belt would slip and the motor come up to speed at once, and the extractor and belt would attain full speed at a rate depending on the friction of the belt on the pulleys.

In the newer forms of drive, these difficulties have been obviated by the use of a small motor of design such that the heat is dissipated outside of the motor. To accomplish this a slip ring motor is used with external secondary resistance and a drum type controller. The motor may be connected to the extractor either by belt or gears. The operation of the apparatus could hardly be more simple. The controller is so arranged that no other apparatus need be touched by the operator. On turning the controller handle to the first notch, the motor starts with all resistance in series. This resistance can be arranged to give a suitable starting torque and is of sufficient capacity that the controller may be left continuously at any notch. The controller is then advanced in the usual manner to full speed position, the entire start being made in one minute for the average extractor.

The operating speed with this form of drive is definite and constant, and the drying is perfectly uniform. The resistance grids are of rugged construction and may be mounted on the wall, a post or under the floor where they will be entirely out of the way. They can be placed at some distance from the motor if desired without detriment. Where belt drives are used the rule usually followed in selecting the speed is to use a motor having a speed as near as possible that of the basket spindle. In this way the motor pulley has approximately the same diameter as that of the spindle and will pull a load as large as the spindle pulley can receive without slippage.

This type of motor drive has all the advantages of other kinds and none of their disadvantages. The set starts smoothly and quickly, is simple to operate, has no hot parts to inflict burns, does not damage belts, is clean and silent, uniform in drying, can be located where desired, does not affect the speed of other machines, can be run independently at any time and is of reasonable first cost. The increase in capacity and uniform drying alone are sufficient to dictate its use.

ADAPTING TECHNICAL GRADUATES TO THE INDUSTRIES.*

C. F. SCOTT and C. R. DOOLEY

THE Westinghouse Electric & Mfg. Company has recently modified its two year course for technical graduates,† principally by supplementing factory and testing room experience with classroom instruction and, by specializing the training in the latter part of the course, adapting it to the particular work which is to be followed later. The present article outlines the conditions and the reasons which have led to the change and describes the general methods which are being followed.

A large step in engineering education was taken ten or fifteen years ago when it was recognized by the industries that the education of the engineering schools should be followed by specific practical training, and suitable shop courses were inaugurated for bringing young graduates into active contact with the apparatus and the methods of manufacture. For many years the Westinghouse Company has received annually several hundred graduates. They have been regularly employed in factory, testing room, engineering department, and the various commercial departments. In this graduate course the men were formerly transferred from department to department and were expected by contact with their work to acquire a knowledge of the construction and use of electrical apparatus and of business methods. Supplementing the regular daily work, an evening lecture course was conducted during one season ten years ago. This was followed by the organization of a club with facilities for lectures, technical meetings and social activities. However, little was done in the way of systematic instruction bearing directly upon factory and office work. While much can be said in favor of a "sink or swim" policy and the value of learning things by personal observation and experience, the conclusion has been reached that better results, on the whole, will follow a modification of this former method, which is open to improvement for several reasons:—

1—Electrical apparatus is now of so many kinds and has be-

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*A paper presented before the annual convention of the Society for the Promotion of Engineering Education, Pittsburg, Pa., June, 1911.

†In addition to the course for technical graduates there is a four-year trades apprentice course and The Casino Technical Night School, having a regular four-year course.

come so specialized that ordinary shop work is no longer a sufficient means of instruction. Furthermore, a fuller knowledge concerning the details of construction and the principles of operation is now essential to the designing engineer and the application engineer.

2—Factory work by a beginner is apt to be inefficient from the standpoint of the employer and the ordinary young man has difficulty in observing and in learning what he should do. The transition from the prescribed lessons and personal supervision of the school life to the shop work is too abrupt.

3—The point of view is apt to be that of the workman who knows only of the construction of the coil he winds, or the arc lamp he assembles, without appreciating why the apparatus is made as it is, in order that it may be reliable, durable and efficient. He may learn what it is without learning why; he may miss entirely the ideas of the electrical and mechanical designers which are embodied.

4—The time available in the factory is too short to enable one to cover the whole ground thoroughly, hence factory experience is ordinarily limited to a few departments and a few kinds of apparatus. The course must cover but few departments if it is to be thorough, while if it endeavors to cover all departments uniformly and comprehensively, it becomes too superficial.

To meet these modern conditions, a new method of training has been inaugurated for the graduates who are now entering the course. The following is a general outline and policy:—

1—The course is divided into two periods. The first is given to general training in the factory, while the second is special, fitting men for the engineering, sales or other departments.

2—In the first period, the work in the factory and testing room is, in the main, confined to a few departments, where the essentials of winding, assembling and testing occupy most of the time and in which a reasonable degree of proficiency is required. Each man enters one of the general departments of the factory; such as the railway and control departments, where railway motors, locomotives and controllers are made; or the industrial department, where small motors and controllers are produced; or the power department, where large generators and motors are manufactured. Each of these departments is essentially an independent factory, carrying on complete manufacturing and testing operations.

3—Supplementing the factory organization, there are supervisors who assist the foremen in making the work of the graduates

effective in the regular manufacture of the company's product, and at the same time aid the young men in acquiring useful knowledge and experience. The shop work is of a practical, serious sort in which the young men learn to be workers and producers and develop a sense of service and of vital responsibility.

4—Supplementing the work in the factory and testing department, a course of technical instruction is given which comprises attendance at class-room meetings during working hours, for approximately four hours per week, during which time the regular rates of compensation are paid. Also the equivalent of at least six hours per week, outside of the regular working hours, is required to be devoted to assigned reading, study or technical meetings. This technical instruction relates particularly to the construction and operation of the apparatus and it directly supplements the work in the factory. The men who are working on a particular kind of apparatus have an instruction period devoted to it each week. Instruction books or appropriate articles are assigned for reading, a list of questions is given to the students beforehand, and in the class-room there are questions, general discussions or talks by the company's experts. For example, on certain days those who are winding coils, meet in the class-room and under the guidance of an instructor, consider the types and forms of coils, the various methods of forming odd-shaped coils, the characteristics of the insulating materials used and methods of applying them, the insulation required on coils of different sizes and for different purposes, the methods of splicing wires and copper strap, the machine-winding and hand-winding of coils, also the cost of the materials and labor. The more purely engineering features, as the ventilation, carrying capacity, eddy currents and the like, receive only secondary consideration at this time.

5—General instruction regarding the various types of apparatus supplements that relating specifically to the factory or testing room work upon which the men are immediately engaged. Thus, comprehensive acquaintance with all types of apparatus is gained through reading, discussions and lectures, accompanied by visits of inspection to the various departments of the works. The young men are called upon to observe for themselves, and to make written and oral reports. For this purpose meetings are held.

6—At the beginning of the second period of the course, the young men take up the special training for the engineering, sales or

other departments. The experience in the first period places both the young men and the company in a position to make an intelligent selection of the department for which they are best fitted.

7—The several departments have direct supervision of their respective training courses. In some cases the work continues in the factory and the testing department along particular assigned lines. In other cases, regular work, under proper supervision, is done in the engineering, sales or other departments, while, in still other cases, a portion or all of the time may be devoted to special study and class-room exercises.

8—The sales department has been conducting, during the past year and a half, a commercial training department for the engineering graduates who are completing their courses and are to become salesmen. These young men study the company's publications; they answer specially prepared questions on the construction and application of the various kinds of apparatus; they give special attention to the engineering and commercial features in the application and use of electric motors as applied to different industries; they become familiar with the details of the systems by which the company conducts its business, and make a study of scientific salesmanship. Part of this work is under special instructors, and part is under the supervision of leaders selected from the class. In the study of apparatus, frequent trips are made to the factory and smaller apparatus is brought to the class-room. Sales demonstrations in which students endeavor to sell arc lamps, meters or motors to other students or to engineers or salesmen, are fruitful methods of testing a man's technical knowledge, his resourcefulness and the force of his personality.

9—The engineering department is actively maturing plans for training men for its work, which will combine experience in factory and in the engineering department in a way most effectively to train men as designing engineers.

10—In addition to the above during the second period, particular courses are given to fit men for the manufacturing, the testing and the erecting departments.

11—The instructors who have immediate charge of the various departments of the training course are specially fitted by education, experience and temperament. Most of them are technical graduates, who have taken the apprenticeship course and have had several years of practical work. They have at hand for guidance and counsel the various officers and engineers of the company

and, when needed, they can call upon them and the experts and specialists in various departments for assistance in the educational work which they are directing. This brings the new men into contact with the older men of the company.

12—The Westinghouse Club, formerly The Electric Club, which has just closed its first year in new quarters continues to contribute to the welfare of the graduate students. During the past year there has been a weekly course of high grade lectures on general topics. There have been 17 technical sections, each meeting every two weeks, and each dealing with some type of apparatus or its application or some phase of the company's organization. The older engineers have taken an active part in these meetings. Excursions by the young men in a number of groups have been made to a score of industries in and about Pittsburg. The club provides a convenient social headquarters for the young men. There are a dozen rooms for reading, writing, general gatherings and amusements, as well as lectures and formal meetings. There is also a large and well equipped gymnasium which contributes to the physical welfare and athletic enthusiasm of the members. The dues, for those on the graduate course, including the gymnasium and The Electric Journal, which is published monthly by the club, are $7.00 per year. The club activities are managed by young men, who find this an excellent means of getting into contact with their fellows and of showing their aptitude for organization and management.

Underlying the purely technical knowledge and experience which nominally form the principal contents of the training course, there is the even more important purpose of developing men. As the electrical industry increases and more exacting requirements are placed upon electrical apparatus, which is taking a larger and more responsible part in the doing of the world's work, there is a demand for greater ability on the part of the engineers and managers who have to do with the production and operation of apparatus and the direction and management of manufacturing and operating companies. Many of those who now hold responsible positions in the various departments of such companies or as consulting engineers, have gained an important part of their experience in the training courses of manufacturing companies. It is the aim in the courses which have been outlined in this article to keep pace with the new conditions and to prepare men for the larger duties and larger responsibilities which they will face in the future as engineers and as men.

THE SELECTION OF ALTERNATING-CURRENT MOTORS FOR ELEVATOR SERVICE

A. G. POPCKE

THE characteristics of the electric circuit and the required horse-power, speed, time rating and starting conditions are the factors which determine the selection of an electric motor for a given installation. For elevator service where the load is intermittent, motors rated on the basis of full load for one-half hour with 55 degrees C. temperature rise have proven satisfactory. From two to two and one-half times full-load torque is required for starting. Induction motors fulfilling these conditions are built both of the squirrel cage and wound secondary type. The squirrel cage motors have high resistance end rings designed to produce the slip which is necessary to secure the desired starting torque.

With the diameter of the elevator drum, the speed of the car and the unbalanced load known, in selecting a motor of this type it is necessary to determine the required horse-power and motor speed, both of which can readily be found by the aid of the diagrams in Figs. 1 and 2. The former is used to determine the speed, after which Fig. 2 serves for selecting the motor to do the required work.

EXPLANATION OF FIG. 1

The factors involved in this diagram are:—1, diameter of elevator drum in inches; 2, speed of elevator drum in r.p.m.; 3, speed of elevator in feet per minute; 4, speed reduction between motor and elevator drum; 5, full-load speed of motors.

The left hand part of the diagram shows the relation between diameter of elevator drum, speed of elevator drum, and speed of elevator, i. e., it represents a general solution of the following equation used to determine the speed of elevator, knowing the diameter and speed of drum:—

Speed of elevator (ft. per min.) $= 3.14 \times$ diam. of drum (inches) $\times$ r.p.m. of drum $\div 12$.

In the diagram each vertical line represents a diameter of drum in inches given at the lower margin. Each horizontal line represents a speed of drum in revolutions per minute given on the left hand margin. Each oblique line represents an elevator speed as indicated. Given any two of the quantities the third can be determined by finding the intersection of the lines representing the known

quantities. The third line passing through this intersection represents the value of the quantity sought.

Example 1—Given a drum diameter of 30 inches and drum speed of 25 r.p.m., what is the speed of the elevator?

Find the intersection of the vertical line through 30 inches diameter of drum and the horizontal line through 25 r.p.m., the intersection is on an oblique line equivalent to 200 feet per minute elevator speed.

Example 2—Given a drum diameter of 40 inches and speed of elevator 250 feet per minute, what is the speed of the drum?

Find the intersection of the vertical line through 40 and oblique line corresponding to 250 feet per minute elevator speed. A horizontal line passed through this intersection represents 24 r.p.m., or the speed of drum.

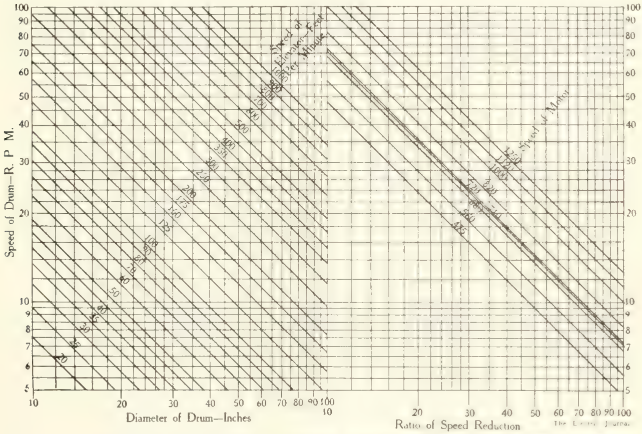

FIG. 1—DIAGRAM SHOWING THE RELATION BETWEEN SIZE AND SPEED OF DRUM AND ELEVATOR SPEED, ALSO SPEED OF DRUM, SPEED OF MOTOR AND GEAR RATIO

STANDARD INDUCTION MOTOR SPEEDS

Motor	Cycles	Poles	Speed
Squirrel Cage	60	8	720
Wound Motor	60	6	1120
" "	60	8	820
" "	60	10	680
" "	60	12	560
" "	25	4	710
" "	25	6	475

The right hand part of the diagram shows the relation between speed of drum, speed reduction between motor and drum, and the speed of the motor. The principle employed is similar to that explained under the left hand side of the diagram. Given any two of the quantities the third can be found as follows:—

Example 3—Given speed of drum 20 r.p.m. and speed of motor 680 r.p.m., what is the gear ratio?

Find the intersection of the horizontal line corresponding to 20 r.p.m. drum speed and the oblique line corresponding to 680 r.p.m. motor speed. A vertical line passed through this intersection represents the ratio sought, which is 34.

If the maximum gear ratio allowable is specified and the speed of drum is known, the speed of motor is determined as follows:—

Example 4—Speed of drum 28 r.p.m. and gear ratio must not exceed 25, what speed motor must be used?

Find the intersection of the horizontal line corresponding to 28 r.p.m. drum speed and the vertical line corresponding to gear reduction of 25. The oblique line corresponding to 710 r.p.m. motor speed passes through this intersection. Therefore on a 25 cycle circuit a 4 pole, 710 r.p.m. motor would be used and on 60 cycles, a 10 pole 680 r.p.m. motor would fulfill the requirements. The 8 pole, 720 r.p.m. squirrel cage motor would also be suitable, the speed exceeding that desired by less than two percent.

The two operations can be combined as follows:—

Example 5—Diameter of drum 40 inches, speed of elevator 250 feet per minute, and gear ratio not to exceed 40, what must be the speed of a 60 cycle motor and also of a 25 cycle motor to fulfill these requirements?

The intersection of the vertical line through 40 inches (diameter of drum) and the oblique line equivalent to 250 feet per minute corresponds to a drum speed of 24 r.p.m. The lines representing drum speed of 24 r.p.m. and gear ratio of 40 on right part of the diagram intersect between 820 and 1120 r.p.m. An 8 pole, 820 r.p.m., 60 cycle and a 4 pole, 25 cycle, 710 r.p.m. motor will be satisfactory in this case.

All values falling between lines can be interpolated with sufficient accuracy for commercial use, and, of course, a standard motor speed must always be chosen.

EXPLANATION OF FIG. 2

This diagram shows the relation between the following factors:—1, unbalanced load; 2, speed of elevator in feet per minute; 3, horse-power of motor.

The curves represent a general solution of the following equation based on an elevator efficiency of 50 percent, which is generally used in problems of this kind:—

$$\text{Horse-power} = \frac{\text{Unbalanced load (lbs.)} \times \text{speed of elevator (ft. per min.)}}{33\,000 \times 0.50}$$

The vertical lines represent speeds of elevator in feet per minute given on the lower margin of the diagram, the horizontal lines represent unbalanced loads given at the left-hand margin, and the oblique lines represent values of horse-power of motor given thereon. As explained under Fig. 1, if any two of the above factors are given, the third can be determined by finding the intersection of

the lines representing the known quantities. The value represented by the third line passing through this intersection is the value sought.

Example 6—Unbalanced load 2 000 lbs., and speed of elevator 250 feet per minute, what size of motor is required?

Find the intersection of the horizontal line representing 2 000 pounds and the vertical line representing 250 per minute. The oblique line passing through this intersection corresponds to 30 horse-power, which is the power required. By means of Fig. 1 and the characteristics of the elevator, i. e., size of drum, speed and gear ratio, the proper motor speed can be selected. If in the last problem the speed reduction must not exceed 40, and if the diameter of drum is 36 inches, Fig. 1 shows that the speed of drum must equal 27 r.p.m. (interpolated). For 27 r.p.m. and a limiting gear ratio of 40, Fig. 1 shows that the speed of the motor must be lower than 1 120 r.p.m. Hence, if the circuit is 60 cycle a 30 hp, 60 cycle, 8 pole 820 r.p.m. motor may be used and the gear ratio will have to be about 31.

Example 7—Elevator drum 36 inches in diameter, speed of elevator 125 feet per minute, unbalanced load 1 500 lbs., gear ratio not to exceed 60 and

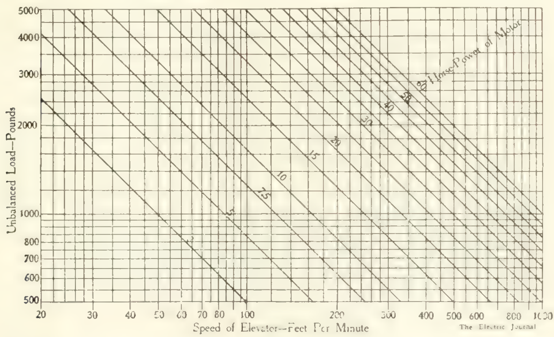

FIG. 2—DIAGRAM SHOWING RELATION BETWEEN UNBALANCED LOAD ON ELEVATOR, ELEVATOR SPEED, AND HORSE-POWER OF MOTOR

electric circuit, 220 volts, 60 cycles, three-phase, what motor should be recommended for connection to this elevator?

In Fig. 1 the drum speed corresponding to an elevator speed of 125 feet per minute, and a drum 36 inches in diameter is 13.5 r.p.m. The limiting motor speed falls below 1 120 r.p.m. Therefore an 8 pole 60 cycle motor should be used. Fig. 2 shows that 11 hp is required under the given conditions or load and speed. Therefore a standard 10 hp (good for 11 horse-power), 60 cycle, 8 pole motor should be used. If a squirrel-cage motor is used the 8 pole motor with a full load speed of 720 r.p.m. (20 percent slip) will be required. The gear ratio will then have to be 52 in order to maintain 125 ft. per minute elevator speed.

The examples given explain the solution of typical problems. The diagrams cover practically all cases, and it is evident that a motor of standard manufacture can be selected for any elevator

application within the limits shown. Special motors require development which necessarily increases the expense and delays delivery. For instance, if the diagram shows that 28 horse-power is required and if a standard rating exists at 30 hp, this motor should be used.

In practice it has been found that squirrel cage motors in sizes up to 15 or 20 horse-power are satisfactory for elevator service.* A speed of 720 r.p.m. has also been found to be most desirable. Therefore 8 pole, 60 cycle motors of the squirrel cage type are mostly used for this kind of service. These motors are very simple in construction and control. The controller is a reversing drum type switch which connects the motor directly across the line. It is located near the motor and is operated by means of a rope or lever in the elevator car. This type of motor is rarely used when the elevator speed exceeds 150 feet per minute since the power will usually exceed 20 horse-power at the higher speeds.

Where a starting current of two and one-half times full load current is objectionable, and when the size of the motor exceeds 20 horse-power a wound secondary motor is commonly used. The use of the high resistance end rings in the larger sizes becomes objectionable on account of the large amount of heat to be dissipated when running at or near full load. With the wound secondary type of motor the resistance is cut out when the motor is up to speed and hence there are no excessive losses.

These diagrams can be applied equally well if direct-current motors are required. The speeds of direct-current motors are not as well standardized as those for alternating current since an unlimited number of speeds is possible.

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*See article on "Alternating-Current Elevator Motors" by Mr. W. H. Patterson, in the JOURNAL for February, 1911, p. 155.

WINDING OF DYNAMO-ELECTRIC MACHINES—XV

PORTABLE INSULATION TESTING OUTFIT

C. S. LAWSON

THE windings of electrical machines are always given a suitable insulation test by the manufacturers before shipment; however, it is usually desirable to subject the apparatus to another insulation test after it is installed and ready for operation. Thus, in the case of a generator installed in a power house, the standard insulation test of twice the normal operating voltage applied to its windings, the connections to the switchboard and the auxiliary apparatus, serves as a reasonable safeguard against subsequent interruptions due to chance defects in installation. With ample testing equipment at hand, factory tests are usually conducted without trouble or delay. However, in making the insulation test on the apparatus after it has been installed serious difficulties may arise in meeting the desired conditions of test for lack of the necessary equipment.

A desirable testing set is one which combines portability and a large degree of flexibility in operation. A description of an outfit of this type, which may readily be moved from place to place in power house or factory, and may be shipped, completely assembled for service, to any distant point is given in this article. This set may be operated on 25 or 60 cycles and from a 110 or 220 volt line.

Since the maximum voltage of rotating machines rarely exceeds 13 200 volts and the standard test voltage is usually twice the normal rated voltage, this outfit should be serviceable for the testing of all rotating machines and transformers and switching apparatus for use on lines not exceeding 13 200 volts normal rating.

The complete set includes a 30 k.v.a., 30 000 to 500 volts, oil insulated testing transformer, a 30 k.v.a., 500 to 220 or 110 volt, oil-insulated regulating transformer, a regulating drum, controlling panel and spark-gap, the whole being mounted on a flat-wheel angle iron truck. Such an outfit completely assembled is shown in Fig. 159. The testing and regulating transformers are of the oil insulated type and are mounted in a rectangular boiler iron tank, the regulating transformer being mounted above the testing transformer, to which it is bolted, so that the two transformers may be lifted from the tank as a unit. The transformers are also bolted to the inside of the tank so that the set may safely be shipped com-

pletely assembled. One high-tension terminal is carried through the cover in an insulating bushing; the other end of the winding is grounded inside of tank and carried to a grounded terminal on the cover so as to be accessible for attaching the testing leads. One end of the primary or low-tension winding of the testing transformer is also grounded for the protection of the operator.

The control panel is made as small as possible to lessen the liability of breakage during transportation. It carries a double-pole switch with fuses and terminals for connecting to either a 220 or 110 volt line. There is also a single-pole circuit breaker, and a set of binding posts connected to the two ends of the primary winding of the testing and regulating transformer. The circuit breaker is connected in the line between the testing and regulating transformers. The binding posts are provided for attaching a portable voltmeter by means of which the voltage impressed on the primary of the testing transformer may be observed while tests are being made The diagram of connections is shown in Fig. 160.

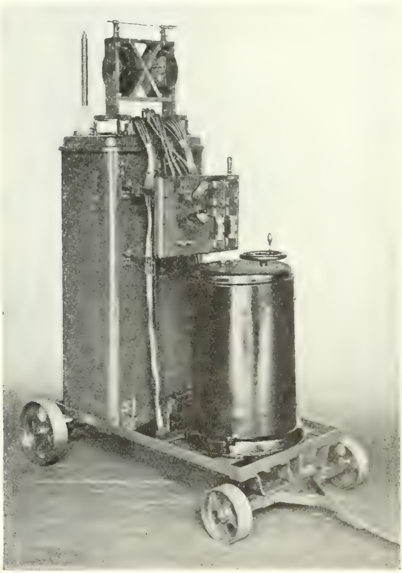

FIG. 159—GENERAL VIEW OF PORTABLE INSULATION TESTING SET

On account of the rise in the secondary voltage of the testing transformer which results from the effects of the electrostatic capacity of the apparatus under test, a voltmeter across the primary winding of the transformer does not always indicate the correct value of the secondary voltage. An adjustable spark-gap with

needle points is therefore provided for connection across the terminals of the secondary or testing circuit. By use of this spark-gap the test voltage is accurately determined. The voltmeter is used more to indicate approximate values as the voltage is being raised to the value for which the spark-gap is set.

Choke coils are placed in series with the spark-gap for limiting the discharge current across the gap, and binding posts are provided for attaching the transformer and testing leads. The spark-gap with its choke coils is carried by a wood frame mounted directly on the transformer cover.

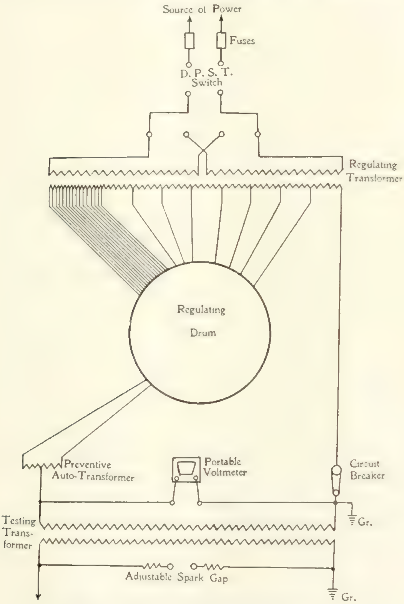

FIG. 160—DIAGRAM OF CONNECTIONS OF INSULATION TESTING SET

By means of the regulating drum and taps on the secondary of the regulating transformer the testing voltage may be varied from zero to 30 000 volts in 127 steps. The secondary of the regulating transformer is divided into a main winding and two "floating" coils. The main winding is provided with taps, which divide it into eight parts, each of which gives a voltage corresponding to that of the two floating coils connected in series. The floating coils in turn have taps which together give a total of 16 steps between adjacent taps on the main winding. Two leads from the primary of the high-tension testing transformer are connected to the secondary of the regular transformer as follows; one lead is connected to one end of the main winding and the other to successive taps on the floating coils, while the coils in turn are connected to the various taps on the

main winding as the voltage is varied. The shifting of connections is done by means of the regulating drum, the coils themselves, of course, not being movable. The method of connecting the two floating coils to taps on the main winding is shown by Fig. 161, in which the two coils are designated as A and B. With the coils in the position shown by A_1 and B_1, adjustment is obtained from zero to the voltage corresponding to the first tap on the main winding, through 16 steps. After the connection has been shifted from A_1 to B_1, the terminals of A_1 are changed so that in effect it assumes a position A_2 and gives corresponding voltage steps between the first and second taps of the main winding. When B_1 has been passed, its connections are in turn shifted so that in effect it has a position corresponding to B_2, between A_2 and the second main tap. The connections of A and B are thus shifted from one main tap to the next throughout the entire range of voltage adjustment.

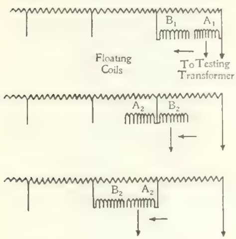

FIG. 161—DIAGRAM SHOWING OPERATION OF FLOATING COILS

The actual connections of the line to the taps of the floating coils A and B is made through a preventive auto-transformer. The line is connected to the middle of this preventive coil, and its terminals connect to adjacent taps of the floating coils. In shifting from one tap to the next, one terminal of the preventive coil is moved at a time, so that the line is not disconnected from the floating coils during the process. The preventive coil is of sufficient impedance to limit the current to a safe working value when it is connected between adjacent taps.

The testing set is designed for shipping in assembled form, with the oil in the tank. All external leads from the apparatus within the tanks are made oil tight, as they are sealed with an oil proof insulating compound. For safer transportation the high-tension terminal may be replaced by an oil tight blind flange. Clamps attached to the truck serve in this case for holding the terminal during shipment, so that when the set is boxed, it is entirely self-contained.

ELECTRICAL ACCIDENTS AND THEIR TREATMENT*

CHAS. A. LAUFFER, M.D.
Medical Director, Relief Department, Westinghouse Electric & Mfg. Company

THE industrial application of electricity brings to the surgeon many electrical injuries that are not mentioned in standard works on surgery, and inadequately presented in current medical literature. The following outline is based upon a rather extensive personal experience in dealing with such cases:—

Electrical injuries, based on their causation, may be classified as due to exposure to flashes and to actual contact. Flashes or arcs occur upon breaking, or momentarily short-circuiting, direct and alternating currents, as for example, where a switch in a heavily loaded circuit is opened by mistake or when a workman at a switchboard allows his screw driver to slip and causes a short-circuit. Although electrical flashes are ordinarily of only momentary duration, the heat developed is often very intense. Painful burns of the unprotected skin or eyes may also result from continued exposure to the rays of an electric arc such as is used in arc welding, although the operator may not have been close enough to the arc to feel any intense heat. Such burns usually do not become apparent until several hours after the exposure. Their treatment is the same as for the heat burns.

FLASHES CAUSING INJURIES TO THE EYES

Eyes which have been exposed to electrical flashes become very red; the suddenly dilated blood vessels of the mucous membrane of the eyes, on both the eyelids and the eyeball, become much congested. There is a copious secretion of tears, a remarkable aversion to light, and intense pain. Often the hair is singed and charred hair, skin debris and dust particles may fill the eyes, contributing to the above symptoms. The mucous membrane covering the eyeball and the eyelids adjacent to the eyeball, which is known as the conjunctiva, is inflamed, constituting a "conjunctivitis." In more marked cases, there appears around the central transparent area of the eyeball, known as the cornea, a zone of red; such a zone of red in the white of the eye, near its junction with the colored part of

*The original material upon which this article is based appeared in *The Medical World* for July, 1911. It has been rewritten by the author especially for the JOURNAL, with the omission or explanation of medical terms. The author emphasizes the fact that wherever possible the care of the eyes and the treatment of burns should be left to a physician. Also, in cases of severe shock the efforts at resuscitation must be begun very promptly by the victim's comrades, and their efforts supplemented by the timely arrival of a physician.

the eye (the iris), is known as an "iritis," and is characteristic of a congestion of the blood vessels within this portion of the eyeball. If the heat of the flash is sufficient, as in the more severe cases, the superficial layers of the transparent cornea are coagulated.

Treatment—The immediate treatment consists in washing the region of the eye and the eyelids with eye-water,* then washing the eye itself. Upon dropping into the eyes a sufficient quantity of three-percent cocaine hydrochloride solution, the debris may be mopped out with clean cotton wrapped on a tooth-pick. The coagulated tissue of the cornea is similarly mopped off.

The immediate relief of pain is secured by cold compresses over the eye, and the chief remedy in the subsequent treatment is cold compresses; merely cotton or a clean cloth laid on ice, or made wet in ice water, and changed by the patient every two minutes. The cold compresses serve to contract the dilated blood vessels, and thus control the painful congestion. They can be employed for an hour at a time, as the patient lies down; not constantly, but every other hour. This enables the patient to get some sleep, for flashed eyes are most painful when he is relaxed and ready to sleep. Eye-water is used every hour. In severe cases adrenalin hydrochloride, 1:5 000 solution, is used every half hour; atropine sulphate, one-percent solution, a few drops every four hours to control the iritis referred to above, if this symptom manifests itself. Also it may be necessary to apply castor oil every two hours, to prevent the eyelids and eyeball from growing together ("synechial adhesions"), if the corneal tissue has been much injured. In the milder flashes the three latter remedies are omitted, as the patient wears smoked glasses and returns to work in two or three days. Recovery is prompt and complete in practically all cases.

It is conceivable that high intensity flashes are capable of seriously affecting the optic nerves in suscetible cases, though such a case has never come under our observation. The *fire* of the flash that singes the hair or burns the skin is but one element in the production of this type of injuries, as eyes may be "flashed" and pre-

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*A serviceable formula for eye water was given in the Jan., 1911 Question Box, No. 374. This formula is as follows:

℞ Sodii Biboric	0.30
Acidi Boric	0.15
Alumini Sulphatis	0.06
Zinci Sulphatis	0.06
Aquæ Camphoræ	30.

M.

Sig. Use freely as an eye wash.

sent the congestion, lachrymation, pain and aversion to light (the cardinal symptoms of flashed eyes), when the person is too remote from the heat of the flash to be burned. As suggested above, the intense light of the electric welding arc will produce a similar conjunctivitis and iritis; the effect probably being due to the ultraviolet rays present in the electric arc. However, the red and blue glasses worn in the helmets of the welders protect them from the high intensity light.

FLASHES CAUSING INJURY TO THE SKIN

Flash burns of the skin are usually burns of the second degree. That is to say, while destroying the outer layer of the skin (the epithelium) they do not injure the inner layer of the skin (the corium) nor the deeper tissues. At first these burns may present a mere congestion; the skin is red, as from exposure to the sun, and they have the appearance of a first degree burn, scarce worth while dressing and bandaging. But there is pain, some redness, and by the second day huge blebs or blisters may have formed. Usually the hair is scorched; often the outer skin is blown off, and the surface looks ragged. Under proper treatment of these cases, there is seldom any formation of pus, and they will heal up, usually without leaving a scar. We have treated many of such burns with the happiest results. We have treated men whose features were so altered by burns, and the eyes so swollen shut, that their own mothers would not have known them. To the uninitiated, it seemed they were scarred for life, yet within two weeks they were able to resume work, and within two months no trace of their burns was discernable.

With sleeves rolled up to the elbow, no gloves, and the face near a switch when it is opened on a circuit carrying a heavy current, the exposure to flash burns is unnecessarily increased.

Treatment—The immediate treatment of flash burns consists in securing the highest obtainable degree of surgical cleanliness with ethereal soap* applied with numerous cotton sponges (using

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*A good formula for ethereal soap consists of:

Ether	4 oz.
Turpentine	1 oz.
Alcohol	3 pints.
Soft Soap	4 lbs.

Water enough to make one gallon.

This soap is especially suitable for cleaning burns and wounds, as it serves to "cut" the dirt and grease, and at the same time renders the region antiseptic.

sterilized absorbent cotton such as is sold for medical uses), and the application of a sterile gauze dressing, well covered with unguentine. We find this ointment uniformly reliable; it soothes the pain, and promotes recovery. A loose gauze bandage is applied, and the part put at rest.

The subsequent treatment consists of daily redressings. When the blebs are large, we scissor them open freely, but allow the outer skin to remain for some days, as it is in itself a splendid protective covering.

These burns must be washed clean, then there is little liability to infection with its pain, the formation of pus, and the resulting long term of disability. But should it become infected, and pus form, we at once trim away the skin debris, so as to allow no pockets for the retention of infection. In the absence of infection, that is, when the pus-producing bacteria do not invade the wound, the dead skin is removed within a few days, after the inner sensitive layer of the skin has had a chance to harden somewhat, and to lose its hypersensitiveness. When the healing has progressed we sometimes apply ten-percent Ichthyol in Petrolatum, to facilitate the formation of normal skin. After recovery, in most cases, the skin remains red and sensitive for some weeks. We instruct the patient to wear canvas gloves, and otherwise protect the new skin from grime and weather, as it is prone to eczema.

The dry open method of treating such burns, namely, that of powdering on Stearate of Zinc freely and exposing them unbandaged to the air, is successful in hospital practice, but not adapted to ambulatory patients, especially those that may live on the streets and in dirty houses, and who may return to work before complete recovery.

CONTACT INJURIES

The two types of contact injuries are shocks and burns. The passage of an electric current through the human body may cause a momentary unpleasantness, the retention of the victim within the circuit unable to release himself, a suspension of consciousness during which he falls, but revives again, or a suspension of animation, requiring artifical respiration.* The artificial respiration helps sustain the action of the heart, hence the necessity of immediate efforts at resuscitation.

The burns from electrical contact are generally of the third

*See foot note at bottom of next page.

degree; that is, there is a destruction of both layers of the skin, and even of the deeper tissues. The real extent is not immediately apparent. The tissues are coagulated, and there is a deep white slough that is slow in separating. At times, fingers are burned to a cinder, or the vascular supply so destroyed as to cause a dry gangrene. These burns are as a rule painless, and upon recovering from the shock the patient may not consider himself burned, but later the discovery is made. In the milder forms they may not report for treatment until some days after the accident, by which time the burn has become infected. But these burns are worse than they look and are obstinate to heal, especially after infection sets in. Ordinarily, in the milder cases, the patient is best treated while continuing at work. In the severer degrees, as above mentioned, they are hospital cases.

Treatment—The immediate treatment in case of such burns consists in surgical cleanliness, secured by ethereal soap applied with numerous cotton sponges. For the milder burns, we prefer Deplettol, or ten-percent Ichthyol on sterile gauze, to facilitate the separation of the necrosed (dead) tissues. When the slough has separated, we commonly employ Balsam of Peru as a dressing and alternate with Thymol Iodide at times. When crusts form under this mode of treatment, we employ zinc oxide ointment to remove them, and continue with the daily dressings until the defect has granulated in and the area is covered with healthy skin.

The severer burns in hospital practice are treated by open dry or wet methods, in accordance with the ideas of the surgeon on the particular service. It is customary to be conservative in waiting for

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*In an article on the "Prone Pressure Method of Resuscitation From Electric Shocks and Drowning," appearing in the JOURNAL for February, 1911, p. 203, the author discusses in detail the three essentials for performing artificial respiration, viz.:

I—The man is laid upon his stomach, face turned to one side, so that the mouth and nose do not touch the ground.

II—The operator kneels, straddling the patient's hips, or kneels by either side of the hips, facing the patient's head.

III—The operator places his spread hands upon the lower ribs of the patient and throws his own body and shoulders forward, so as to bring his weight heavily upon the lower ribs of the patient. The operator's downward pressure should occupy about three seconds, then his hands are suddenly removed. Squeezing the chest in this manner forces the air out of the lungs. On release of the pressure the elasticity of the chest walls causes them to expand, and the lungs are refilled with fresh air. This act should be repeated indefinitely at the rate of about twelve times a minute. Any evidence of returning breathing should encourage the operator to continue his efforts. It often requires one-half hour to two hours.

gangrene to demark the necrosed tissues, rather than resort to immediate amputations, inasmuch as the boundaries of the damaged tissues cannot be determined immediately. Burns of the palms which to the uninitiated seem trivial may necessitate the amputation of the hands, due to necrosis of the tendons.

While such accidents are relatively very few, yet despite all precautions some will occur. It is the function of the surgeon to restore the victim of an electrical accident to normal, and not entirely in his province to know the voltage that has produced the injury. The determination of the source and the probable voltage and amperage of the accidental contact is a problem for the electrical expert. Yet the inquiry as to what current is liable to produce a fatal result is important. Unfortunately the records available are quite meagre, and the various opinions as to what constitutes a dangerous voltage under different conditions are inconsistent.

This outline of a practical method of treating electrical injuries is submitted to emphasize their curability, not to enable the injured to be their own physician; the skill of the surgeon, and his aseptic dressings and redressings, are essential to a rapid recovery. It is well, however, to be prepared for emergencies by having on hand certain of the essential curative agents referred to in the present discussion, in order that effective first aid may be administered. This is especially important for electrical operators in localities remote from any source of immediate medical assistance.

EXPERIENCE ON THE ROAD

AN EXCITER SET WITHOUT VOLTAGE ADJUSTMENT

E. T. SILL

DIRECT-CURRENT motor-generator sets in which the respective machines operate at different voltages are usually self-excited. A peculiar case of trouble arose in connection with such a set as a result of the shunt field circuits of the motor and generator having been interconnected by mistake. This motor-generator was installed in a power house as an exciter set for two turbo-generators which supplied power to two 250 volt rotary converters. The motor of the set received its power from the 250 volt direct-current side of the converters, while the generator delivered power to the exciter bus-bars at 125 volts. The connections for the exciter set, when properly connected, are shown in Fig. 1.

On starting the outfit, the generator gave only 120 volts, regardless of its field rheostat. This rheostat, which had a resistance

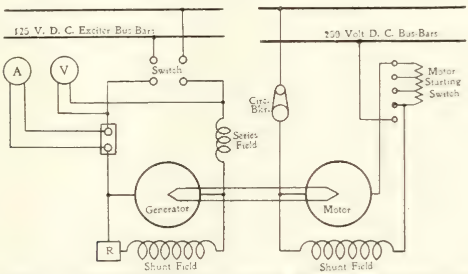


FIG. 1—CONNECTION DIAGRAM FOR MOTOR GENERATOR SET

of 25 ohms, was accordingly replaced by one of 80 ohms resistance; however, but little variation in the voltage resulted. As 120 volts was satisfactory for the excitation of the turbo-alternator fields under ordinary operation, the equipment was started without any immediate attempt at solving the difficulty. Later, a trouble man was detailed to investigate.

A voltmeter connected across the rheostat terminals *R*, Fig. 1, indicated no voltage drop with the resistance all out, and as the resistance was cut in it indicated a rising voltage, up to 140 volts; yet, the voltage obtained at the generator terminals was only 120 volts. The voltage between the field side of the rheostat and the plus terminal of the machine was then measured. This should have given the voltage drop in the shunt field windings of the generator. With the

rheostat resistance all cut out this reading was 120 volts, and as the resistance was cut in, this voltage gradually decreased to zero and in turn rose to 20 volts in the opposite direction with the resistance all in. As before, the terminal voltage remained at 120. An ammeter was then inserted in the field circuit adjacent to the rheostat and the current was found to be 2.7 amperes with the resistance all out and 1.7 with full resistance in circuit. It was evident from this that the circuit included additonal resistance still unaccounted for. It was calculated that, to give the voltage drops, as measured, with currents as indicated by the ammeter, the total resistance of the field circuit must be approximately 136 ohms, and that an impressed voltage of about 367 volts must be involved. As the available voltage from the generator itself was only 120 volts, and as it was noted that the sum of the terminal voltages of generator and motor was 370 volts, interconnection of the two fields was suspected.

When a shut-down of the plant gave an opportunity to trace out the field circuits by means of a magneto testing set, it was found that such a mistake in connections actually had been made at the switchboard. The wire from the generator field had been connected to the motor starting switch and the lead from the motor field had been connected to the generator rheostat.

The connections as made resulted in an excitation of the motor such that it operated at approximately normal speed when the resistance of the rheostat R was all cut out, but when the resistance was all in circuit, while tending to decrease the generator voltage, it also caused the motor to increase in speed sufficiently to keep the exciter voltage practically constant. The noise of other machines in the plant allowed the change of speed of the set to pass unnoticed.

MOTOR TROUBLE RESULTING FROM POOR VOLTAGE REGULATION

B. B. BRACKETT
Professor of Electrical Engineering, South Dakota State College

MR. LEONARD WORK'S experience, as related in the JOURNAL for June, 1911, recalls a case of trouble experienced with a two-phase induction motor, which would not start its load because of serious fluctuations of voltage at the source of power. A municipal plant was equipped with a 150 kw, two-phase generator, direct-connected to a hydraulic turbine. As the main load consisted of arc lamps for street lighting and a considerable incandescent lighting load in public buildings, it had not been

considered necessary to provide an automatic governor for the hydraulic turbine. During the day time the plant was nearly idle; in the evening, when the practically constant lighting load came on, the gates were opened to a definite point by means of a hand wheel, and then only slightly changed as the conditions might demand. With this method of operation no trouble had been experienced.

It was thought that the plant might profitably be used in the day time to supply power to a nearby stone crusher. Accordingly, a suitable motor of standard make was purchased and installed. But those in charge found that they could not make the machine even start the crusher. Some "expert" assistance was evidently required.

The connections were examined and found to be correct. The circuits were complete, and on open-circuit the line voltages at the motor and on the motor side of the starter were also found to be correct. With the belt off the motor started satisfactorily and ran at normal speed. However, with the belt on, it would not start, although a hand—such as should have been greatly exceeded by the motor torque—pull on the belt was sufficient to start the crusher. Every attempt to start the motor under load resulted in a large drop in voltage at the transformers and blowing of the fuses, and no amount of care in handling the starter would prevent these results. As it did not seem possible that a 15 hp motor, even under unfavorable starting conditions, could pull down the voltage of a 150 kw generator, attention was turned to the source of power.

Inquiry at the power station made the reason evident. It had been customary, during the day time to keep the gates all but closed, thus preventing the generator from running too fast, and still maintaining normal voltage on the lines. Accordingly, when the motor load was connected, the speed and voltage of the generator dropped very rapidly, and in ten seconds the fuses opened the circuit and thus restored the no-load conditions. The attendant at the power station said that he had noticed that the speed dropped several times that morning, but that each time, before he got to the gate wheel, the speed came back to normal.

By comparing watches with the attendant and instructing him to begin to open the gates at a specified instant, the motor was made to start its load at this pre-arranged time without the least trouble. This resulted in a simple code of signals to warn the attendant when it was desired to start or stop the motor, and thus the station and load were operated together as well as could be desired.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburg, Pa.

591—**Resistance Racks for Loading Machines on Test**—An adjustable resistance device for furnishing testing load is shown in Fig. 591 (a). The sections of resistance or lamps can be connected in series, but I see no way to throw the switches so as to get more than

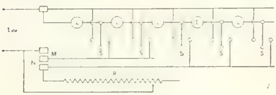


FIG. 591 (A)

every other one in parallel. I assume that the double-throw, single-pole switches are arranged to throw to the right or left from the center. If it is possible to obtain a connection which will put all lamps in parallel please explain.
F. G. F.

To parallel all lamps, assume that the switches are numbered 1, 2, 3, 4 and 5. By throwing switch *1* to the right and switch *2* to the left, two lamps will be in parallel; then if switch *3* is thrown to the right, three lamps will be in parallel and by throwing switch *4* to the left and switch *5* to the right, all five lamps will be in parallel. W. J. B.

592—**Sparking Commutator** — In spacing brushes on a direct-current machine should the actual space rather than the number of bars between brushes be considered, and why? What is a good "eliminating process" to pursue in seeking to eradicate insistent sparking of a rotary converter? D. D. P.

Use actual space rather than number of bars between brushes for the reason that, if there is any variation in thickness of bars or mica, the number of bars between brushes will change upon rotating the armature somewhat and the net average result will not be obtained. See that the brushes are properly spaced, that they are on the electrical center for average load carried, that they fit the commutator and are lubricated regularly by applying a small quantity of oil to the commutator by means of a cloth. Use only such brushes as are recommended by the manufacturers of the rotary converter. Keep the commutator and brushes clean. If the commutator is rough or eccentric, true it up with a tool or stone. Operate the converter at as near unity power-factor as possible. Investigate whether the load exceeds the normal rating of the machine. The wrong brush may possibly have been specified. In case you cannot eliminate the difficulty, it would be advisable for you to take the matter up with the manufacturers of the machine, giving a complete report including all operating and load conditions. J. L. Y.

593—**Homopolar Generators** — *a*—Have homopolar generators been used commercially, except for furnace work and as exciters? *b*—What is the maximum voltage that can be generated by such a machine? *c*—Have they ever been used as motors?

a—Yes. This is covered by No. 379 Feb., 1910. *b*—The maximum voltage is limited only by the number of collector rings that can be used and problems of insulation. This type of machine is best suited to large capacities or very low voltages, for high speed drive. *c*—We have no knowledge of their use as motors, although they could probably be so operated. (See also No. 379.) W. A. D.

594—**Paralleling of Two Separated Direct-Current Generators**—The traction system of this company is

supplied with power by a 350 kw motor-generator set connected to the 2 300 volt circuit. The direct-current side is compounded for 720 volts at full load; the voltage at no load is 500. The company proposes to install a 500 volt, steam driven direct - current generator compounded for constant voltage at the power plant. The generator at the power plant will be connected to the center of the traction line at the same point as the motor-generator set through 2 000 feet of No. 00 copper. Will these generators work in parallel? R. K. F.

Probably not, because at the point of feeding into the system from the two generators, the voltage supplied by the 350 kw machine will be much higher than that from the proposed 500 volt generator, and this machine will tend to drive the other as a motor. For parallel operation in this case the 350 kw machine should have its regulation changed so that it will give 500 volts at no-load and 500 volts at full-load. The requirement for parallel operation in such cases is a drooping characteristic on all machines, i. e., the voltage should fall off slightly as the load increases. This may be obtained, if the machines are close together, by adjusting their compounding so that the voltage at full-load shall be a little less than at no-load; or, if the machines are some distance apart, as in the present case, the machines themselves can be given a constant potential characteristic, the necessary droop in voltage being given by the drop in voltage in the feeder wires. W. A. D.

595—**Effect of Field Adjustment on Current of Alternators**—Several belt-driven alternators, three-phase, 2 300 volts, feed directly into a transmission line. No. 2 alternator is a 50 ampere machine, driven by a small Corliss engine. It is possible by adjusting the field rheostat of this machine to reduce the current shown by its ammeters to zero. When so adjusted, the sum of the readings of the other machines is but slightly greater than the total current leaving the station. Cutting out the field resistance of No. 2 entirely will cause its ammeters to read 30 amps per phase, but the currents of the other machines in parallel with it increase correspondingly, i. e., their total is 30 amperes greater than before. Apparently No. 2 is delivering no power whatever, and altering the field strength simply heats up all machines the more, by setting up 30 amperes of current, 90 degrees out of phase, between the machines. Is this correct? R. K. F.

When alternators operate in parallel, the distribution of load between the several generators will depend upon the relative speed regulation of their prime movers, not upon the amount of resistance in the different field windings. Unless the speed is adjusted while the field strength is being changed, the armature current cannot be reduced to zero. In case the field resistance of one of the generators is entirely cut out, a wattless current will flow in the armature of that generator, thereby tending to keep its voltage the same as that of the other generators, in which case the other machines must furnish this wattless current. The assumptions of the question therefore are correct.

E. M. O.

596—**Refusal of Two-Phase Induction Motors to Reverse**—It has been observed that at times a squirrel-cage induction motor will not reverse its rotation when the current in one of its phases is reversed, but instead will slow down, and continue to rotate in the same direction, at a certain definite speed. The following is an example: A 30 hp, 220 volt, 1 245 r.p.m., two-phase, 66 cycle induction motor is running light, and 120 volts, two-phase, is applied to its terminals, so as to reverse its rotation. However, it merely slows down to 410 r.p.m., drawing 244 amperes per phase, and developing an appreciable torque. Will you please give an explanation of this action of the motor? H. B. D.

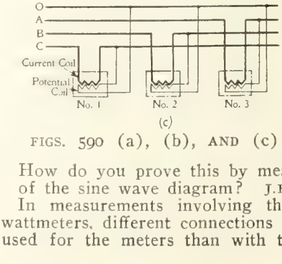
The reason for this action is not positively known. It has been proven repeatedly, however, that the torque

due to the third harmonic currents operates in a counter direction to the main torque. When the connections are reversed the main torque tends to reverse the motor while the torque due to the third harmonic current tends to keep it rotating in the same direction at one-third speed. If the motor characteristics are such as to favor third harmonics this counter torque may be of sufficient magnitude to prevent the main torque from reversing the motor, especially as the main torque under the conditions of reversing is relatively small. The action is more apt to occur with two-phase motors, as the higher harmonics are more liable to be pronounced. Sometimes two-speed motors do not come up to speed on account of this same counter-action effect of the third harmonics, the cause probably being that they are wound with rather small coil throw (pitch), which again favors the higher harmonics. R. E. H.

597—Cross-Connections on Armature—What are the advantages of cross-connected commutators? When are they used? H. D.

Cross-connections are used on armatures that have a multiple or a series-parallel winding. They are not necessarily made on the commutator but may be made also at the rear end of the armature, connected directly to the armature coils. On a multiple wound armature, the armature coils lying between two adjacent brush arms are influenced only by two main poles; when, on account of dissymmetry in the magnetic system, the air-gap densities under these two poles are different from those under other poles, then a voltage will be generated between these two brush arms different from that on the other armature circuits, causing the brush arms of the same polarity to receive different potentials which will make an additional current flow through brushes and brush holder connections. These additional currents will overload the brushes and may cause sparking, and will heat the commutator. In making cross-connections between points of the armature winding that have the same potential (the number of points of the same potential on a multiple wound armature is equal to the number of pole pairs) these additional currents will flow through the cross-connections instead of through the brushes, which obviously will improve the operation of the machine. However, the principal improvement is due to the fact that additional currents, flowing through the cross-connections and the sections of the armature winding, are alternating currents which lead or lag with respect to the magnetic fields, and which therefore exert magnetizing or demagnetizing effects on the fields. These currents always flow in such a direction as to strengthen the weaker poles and weaken the stronger ones. In consequence of this equalization of the pole strengths the voltages of the armature circuits are equalized also, so that they can all deliver approximately their share of the working current. A. B.

598—Three vs. Two Wattmeters for Measurement of Power—Three-phase power can be measured with two integrating wattmeters and three integrating wattmeters. Therefore the sum of the speeds of the two wattmeters must be equal to the sum of the speeds of the three wattmeters on the same circuit, i.e., any one of the two wattmeters must be running faster than any one of the three.



FIGS. 590 (a), (b), AND (c)

How do you prove this by means of the sine wave diagram? J.H.J.

In measurements involving three wattmeters, different connections are used for the meters than with two

wattmeters and different voltages are applied on the potential coils. When measuring power with two meters, the connections shown in Fig. 598 (a) give phase relations as shown in Fig. 598 (b), in which $OA =$ current in A, $OC =$ current in C, $AB =$ e.m.f. across lines A and B, and $BC =$ e.m.f. across lines B and C. On meter No. 1, current $= OA$ and e.m.f. $= AB$, on meter No. 2, current $= OC$ and e.m.f. $= BC$. With three wattmeters, connection is made to the neutral, as shown in Fig. 598 (c). In this case the phase relations are, OA [Fig. 598 (b)] = current and potential on meter No. *1*; $OB =$ current and potential on meter No. *2*; $OC =$ current and potential on meter No. 3. It can be seen that OA is smaller than AB and therefore the meter connection with current OA and voltage OA (three meter method) runs slower than the meter connected with current OA and voltage AB. At unity power-factor the latter will be just 50 percent more than the former. Similar relations hold in the case of the meters connected with current OC and e.m.f's. OC and BC. A.W.C.

599—Single-Phase Motor Cars in Operation—Recently a statement was made that in the service of the New Haven road, no motor cars were being used, all traffic being carried on by the electric locomotives and trailer cars. The speaker further stated that, as far as he knew, no cars of the motor type, such as are used on the Interborough direct-current lines, have yet been built for the high tension alternating-current system. Is this so? The reason I ask is because I have an idea that there is a single-phase system running up the Napa Valley in California which uses these cars. Will you kindly inform me whether they did or are using motor cars on their alternating-current system and, if not, are such cars being successfully used elsewhere? W. F. B.

Two years ago it was true that no multiple-unit type of care were operated on the N. Y., N. H. & H. R. R. The New Haven has multiple-unit cars in operation on the New Canaan branch, also one train on the main line between Stamford and New York. They have ordered more equipment. Practically all of the single-phase roads operate cars on the multiple-unit system. In some cases they run with one-car trains, but can couple as many as desired in a single train. The Chicago, Lake Shore & South Bend R. R. operated a train of eleven cars last summer. Multiple-unit trains can be operated as readily on a single-phase railroad as on any direct-current roads. The Vallego, Benica and Napa Valley 3 300 Volt Railway is described in the JOURNAL for Nov., 1906, p. 657. N. W. S.

600 Condenser Located at Distance from Engine—What loss in efficiency would result through operating a 22 and 44 by 42 inch engine with barometric type condenser located 80 feet from low pressure cylinder, instead of adjacent thereto? The pipe is run horizontal, is free from bends and is the same size throughout. The air pump is located at the condenser. J. B. A.

The reduction in vacuum resulting from long pipe connections cannot be established readily. It would be a safe assumption, however, to allow approximately one-half to five-eighths inch loss in a straight run of eighty feet, providing the line was well built and made air tight. The efficiency of the compound engine would be effected in the neighborhood of one percent. E. D. D.

601—Use of $\sqrt{3}$ in Three-Phase Calculations—Please explain why the constant 1.732 ($= \sqrt{3}$) is used in three-phase calculations? C. A. T.

This constant enters into the relation between the voltage or the current measured in the line and the voltage or current actually present in the windings of a three-phase machine. If the machine is Y-connected, then evidently the current in the line and the current in the winding is the same, since both are in series. The voltage between any two lines, however, is the resultant voltage from the two phases between these

lines, so that if the voltage from a terminal to the neutral point of the Y is equal to V, then the voltage of any two phases can be shown to combine to $(V+V) \times \cos 30$ degrees $= V \times \sqrt{3}$, which is the voltage measured between the lines. If again, the machine is delta-connected, the voltage between lines is the same as the voltage of each phase in the machine, but here the current of any two phases, say each $= C$, will combine to $= (C+C) \times \cos 30$ degrees $= C \times \sqrt{3} =$ current in the line. H. L. B.

602—Single Alternating - Current Conductor in Iron Conduit—The National Board of Fire Underwriters prohibit the installation of a single alternating-current carrying conductor in an iron conduit. Is this because of possible prohibitive impedance loss caused by self-induction, eddy currents, etc., or the mutual induction between pipe and conductor, thereby causing a difference of potential between the two? Will the placing of a lead sheath about the conductor before its installation in the pipe do away with the difficulty, and if so, why? H. D. A.

The Associated Factory Mutual Fire Insurance Companies' edition or the National Electrical Code, to which the inquiry refers, contains, under Rule 24-p, the following explanation of the reason for prohibiting the running of a single alternating-current cable in iron conduit:

"With alternating-current systems, if the wires of the same circuit are in different iron conduits, there will be trouble from inductive losses, and under certain conditions the conduits may become dangerously heated. This trouble disappears if the two or more wires of the same circuit are drawn into the same conduit."

The above sets forth clearly the reason for the requirement under rule 24-p. The addition of lead covering would not obviate the difficulty in any way. C. E. S.

603—Tinning Carbon Brushes—Please indicate proper method of tinning carbon brushes, or preparing them for tinning, for the purpose of attaching "pig tails." G. K. M.

In order to tin carbon brushes satisfactorily, they must first be copper-plated. The plating may be done by cleansing the brushes thoroughly in benzine, then in hot water, and then placing them in a copper-plating solution made up in the proportion of one and one-half pounds copper sulphate, four ounces sulphuric acid and one gallon of water, which should make a solution having a specific gravity of practically 15 degrees Baume. The plating voltage may vary over some range, but should be at such a rate as to give a good, even and dense coating. After plating, the brushes should be washed in hot water, dried in sawdust; they may then be tinned on the plated part in the same manner as any other copper or copper-plated material. C. E. S.

604—Effect of Speed on Efficiency and Life of Motor-Generator Set—Please state advantages or disadvantages as regards operation, efficiency and life of a 300 kw synchronous moter-generator set, designed for 900 r.p.m. compared with one designed for operation at a speed of 720 r.p.m. The set in question consists of a 2 200 volt, three-phase synchronous motor, direct-connected to a 250 kw, 125 volt direct-current generator E.W.B.

With the speeds in question, the difference in efficiency and life of the two sets would hardly be measureable. When an extremely high speed is compared with an extremely low speed, there is undoubtedly some difference in favor of the lower speed set in both respects. F. D. N.

605—Installation of Tirrill Regulator—Please give method of equipping a three-phase generator with a Tirrill regulator, i. e., the correct procedure for connecting a machine to the switchboard for the first time? S. W. K.

Have the exciter and alternating-current generator operating connected to their bus-bars, with alternating-current feeder switches open; if these conditions cannot be obtain-

ed, then the equivalent must be produced. With the switches all closed for running condition, except on regulator, and the resistence all turned out of the alternating-current generator field rheostat raise the alternating-current voltage to its no-load value, and if the regulator is for a 125 volt exciter and the exciter voltage is less than 70 volts it should be raised to that voltage by turning sufficient resistance into the generator field-rheostat to give normal voltage on the alternating-current generator with 70 volts on the exciter; the position of the rheostat handle should then be marked. If more than 70 volts on the exciter is required to give the normal no-load voltage then the alternator field rheostat should be left all turned out. The above is all to be done under normal speed conditions. With adjustments as above and normal alternating-current voltage and 70 volts on the exciter, put the regulator into service after it has been adjusted to the normal alternating-current voltage by counter-weight, etc., then connect the exciter rheostat in, whereupon the regulator should hold the voltage at normal; then open the rheostat shunt circuit switch on the regulator and time the voltage drop; the opening and closing of this switch should be repeated. Each time let the alternating-current voltage become normal and keep turning in at each trial a little of the exciter field resistance until the time required for the alternating-current voltage to drop from normal to a point 65 percent below normal is about seven seconds. The exciter field rheostat should be marked at this point so that it can always be turned to the same point in practice, without causing fluctuations in the voltage. The above tests and adjustments should be made on all generators and exciters operating in parallel. For paralleling exciters, with all adjustments made as above, make the voltage of exciter to be put in service equal to that of exciter service, then close the exciter switch to bus-bars after which close the rheostat shunt circuit switch on regulator, then turn exciter field rheostat to the marked running point, and if necessary to equalize the load between exciters, do so by means of the equalizing rheostat. The paralleling operation for two or more alternators is as usual. Make voltage of generator to be put into service equal to voltage of generator already in service, then synchronize and close main switch to bus-bars, and turn generator field rheostat to its marked running point, and equalize the load or cross-current if necessary by adjusting the governors of the prime-movers. A.A.T.

606—Decomposition of Lead Conduit Imbedded in Cement—A contractor recently installed the lighting wiring for a large statute, which comprised four clusters of lamps. Two-conductor lead covered cable was carried up to the side of the pedestals, and from this point to the respective groups of lamps it was imbedded in cement. This installation was in but a short time when a short-circuit developed which necessitated tearing down the installation to locate the trouble. It was found that the lead covering on the cable where the wire came in contact with the cement, was completely decomposed and the insulation on the cable was partially eaten away, causing a short-circuit. The lead covering was converted into a reddish powder which presumably was oxide of lead. What is your explanation of the action which took place? C. V. A.

There is nothing in ordinary cement which would cause the deterioration mentioned. The red powder found in this particular case was evidently red lead which is an oxide and which must have been formed in the presence of considerable heat and a limited amount of oxygen. The complete oxidation would give litharge in place of the red oxide. It is likely that the short-circuit developed through some injury or deterioration of the insulation of the cable, and that the production of lead oxide was a result and not the cause of the short-circuit. C. E. S.

607—Current in Generator Bearings—A two-bearing type of waterwheel generator with water-

wheel over-hung was discovered to have current flowing in its shaft and bearings. This ran at times as high as 90 amperes. This condition has been noted in other plants at different times in the past, but no one seems to be able to give a definite reason for its existance. Why? C. E. H.

This condition has been noted on a large number of electric generators. In general, the larger the size and capacity of the generator the greater is the tendency for current to flow through the bearings. The cause of this is undoubtedly due to the fact that the shaft of the generator carrying the rotating field acts to a certain extent as a single turn of a magneto-electric generator, the return current being through the bearings, pedestals and bed-plate. So far as can be determined, the cause of the electro-motive force appearing in this circuit composed of shaft, pedestals and bed-plates, is some small dissymmetry of the magnetic conditions in the machine, this dissymmetry being either in the field magnetic circuit or the armature magnetic circuit or both. In small machines this has not been sufficient to give rise to any difficulties; however, in large machines it has in a few instances caused certain difficulties with bearings. It has been found impossible to build the magnetic circuits of generators with sufficient symmetry to be sure that there will be no electromotive force of this kind. As a consequence, the best remedy to apply when this occurs is to interpose an insulation in the circuit through which the current must flow. The best point to introduce this resistance is usually at the foot of one or both of the pedestals carrying the bearings. The electro-motive force introduced in the shaft circuit is extremely small but on account of the large section of shaft, pedestals, etc., this small electro-motive force may cause considerable current to flow. The remedy of introducing insulation into the shaft circuit has been found to be a satisfactory one. Usually this current must be comparatively large before any harmful effects are obtained. P. M. L.

CORRECTIONS

In table I. of the article on "Relation of Load to Station Equipment," in the July, 1911, issue, p. 626, the words "with" and "without" in the first two items should be interchanged.

In the answer to No. 578, July, 1911, on "Reversal of Wattmeter," the first word in the eighth line of the answer should be "lagging" instead of "leading." Through an oversight this answer was given with the understanding that the circuit broken at *A* was the shunt circuit of the meter and not the line itself. If the main power line is opened at *A*, the result is single-phase power, and the meter will therefore always rotate in a forward direction. This method of opening one of the main power lines is often used in checking polyphase connections, for the simple reason that when the connections are correct, this will be indicated by the fact that the meter rotates in the forward direction.

Attention has been called to a slight error in calculation in connection with the answer to No. 549, May, 1911. With the figures for current given, it should be noted that the cables will be overloaded; although the question does not concern their carrying capacity. Also beginning with the twentieth line, the answer should read as follows:

"This gives reactance volts for the cable equal to 26.7, and resistance volts equal 28, which means a regulation of $26.7 \times 0.6 + 28. \times 0.8 = 38.4$ volts. The transmitting voltage would be 538.4 and the percent regulation $38.4 \div 538.4 = 7.15$ percent, very much better than 10 percent. Then further on in the answer, 5.1 percent would become 8.1 percent regulation, and 2.8 percent would become 4.4 percent."

THE
ELECTRIC JOURNAL

Vol. VIII SEPTEMBER, 1911 No. 9

Development of the Small Steam Turbine

The article by Mr. Dreyfus on "Steam Turbines for Electric Stations of Moderate Size" is of more than usual interest. As the steam turbine has substantially displaced the reciprocating engine in the larger stations, it seems but a logical step for it to find equally profitable adaptation in the smaller plants. Within the past two years a full line of sizes has been developed for the operation of both alternating and direct-current generators. It has required a good deal of time to bring about this result. In the direct-current units it was necessary to harmonize the turbine and generator speeds, maintaining safe limits of mechanical design and achieving also efficiencies which would fall well within the standards of good practice. In the alternating-current units there was the one obstacle of achieving economical operation of the turbine in small sizes at the speeds fixed by the frequencies employed.

Companies having stations of moderate size with units of from one hundred to five hundred kilowatts may now avail themselves of the advantages which the steam turbine has brought to the larger plants. In a greater degree, perhaps, may they enjoy the advantages of simplicity and greater reliability, for the smaller station with its many duties falling upon the one managing head, must essentially be free in its daily work from operating complications and mechanical difficulties. In the absence of the facilities that exist in the large stations, the power plant itself must be as free from trouble as it is in the nature of machinery to be. And when in the steam turbine, this quality is combined with the many other features that have made the large turbine such an economic success, we may expect henceforth to witness its extended use in the smaller plants.

E. H. Sniffin

The A. I. E. E. Secretary

When the Engineering Societies Building was dedicated four years ago gold medals were presented to the Secretaries of the three founder societies each of whom had held the office for about twenty-five years. Since that time Prof. Hutton of the Mechanical Engineers ceased to be Secretary when he was made President of the Society; Dr. Raymond of the Mining Engineers has retired from active secretaryship, and now Mr. Pope of the Electrical Engineers has resigned and has been made Honorary Secretary. The engineering profession owes a debt of gratitude to them for the important part which they and the societies to which they gave the best years of their lives have had in the engineering advancement of the past quarter century.

When Mr. Pope began work in the electrical field with the Hughes printing telegraph in 1858, the Pacinnotti ring and the Gramme armature had not yet been invented. Dynamic electricity as we now know it was yet unborn. When he became secretary of the Institute in 1884, the incandescent lamp and the electric motor were in the first few years of their commercial application and the present essential features of the alternating-current system were unknown.

The substantial growth of the Institute is itself the best testimonial to the success of Mr. Pope's life effort. The Institute has been his; it has received his best thought, his best service, his best devotion and those of us who have been privileged to come into closer relations with the Institute management have almost come to regard Mr. Pope as the personal embodiment of the Institute; others have come and gone, he has remained. In the future he will fortunately continue to serve the sections and branches, now numbering over 60, the outcome in a large measure of his foresight, confidence and fostering care.

The Institute has reached a place where those entrusted with its management may well take deep thought as to its future. New problems and larger responsibilities are confronting the electrical engineering profession. The need for the kind of professional cooperation which such a society affords increases, and on the other hand the opportunities for aiding in the development of efficient engineers and engineering methods have become larger. As the Institute is now an organization of over seven thousand members with an income of nearly one hundred thousand dollars, it has become a greater and greater tax upon the time and energies of the

President to take the initiative and direct its wide activities, particularly since this office is conducted in addition to regular professional duties. Hence, it may well be considered whether the Secretary of the Institute should not be a man who can not only counsel with and carry out the policies of the President and the Board of Directors, but who will himself be able to deal constructively with the large professional and engineering problems which now fall within its scope. There are also other progressive relations in which the Institute, as representing an important part of the engineering world, should take a larger constructive part in the shaping of those public and national policies which involve engineering affairs and in which sound engineering is essential. It is a situation involving new conditions, requiring new policies and calling for new men. It is no reflection upon the past to believe that the future has still larger things in store. Surprising progress has already been made. But we have not reached the saturation point in our curve of progress and it may require new ideas and renewed activity to maintain effectively the onward movement.

CHAS. F. SCOTT

Gauging Illumination by Photographs

The illustrations accompanying the article by Mr. Clewell, in the present issue of the JOURNAL, afford an unusual opportunity for comparing the results produced on a photographic plate by various light sources since they include examples taken by tungsten lamps, mercury vapor lamps, flaming arc lamps, and by daylight. As is well known, the intensity of illumination cannot be gauged from a photograph, since an increased exposure will allow the making of a correctly timed negative in an exceedingly poor light, and the resulting print may appear to be from a well lighted interior.

An interior lighted with lamps of equal intensity, as gauged by the eye, but richer in actinic rays such as the mercury vapor lamps, will seem more brightly lighted in a photograph, even with equally timed exposures, with plates similarly developed and printed than one in which the source is weak in actinic rays, as the flaming arc. As a matter of fact, photographers do not give equal exposures under such conditions, unless specially requested, and even when equal exposures are made for a definite purpose, development and printing are almost never the same. Hence even when photo-

graphs of equal exposure are compared the results are liable to be misleading, as the photographer can usually make an interior appear well lighted or dimly lighted at will.

On the other hand, the uniformity of the illumination can readily be compared by means of photographs. Except in cases where the color of the objects photographed produces a different effect on the plate than on the eye, the relative illumination of objects will be the same in photographs as in the original interior and shadows can easily be detected. Here again, however, appearances may sometimes be deceptive, as the degree of intensity, or contrast, can be varied over a wide range, and the photographer, unless especially instructed otherwise, endeavors to produce a print of normal intensity and contrast, regardless of the character of the negative or the conditions in the interior shown.

Glare or freedom from glare can be judged accurately from a photograph, except where prints from ordinary plates are compared with prints from double coated plates. As practically all night photographs are taken on the double coated plates, the amounts of halation around the lamps may ordinarily be taken as an indication of their brightness relative to the objects illuminated.

It is a curious coincidence that whereas objects appear more sharply to the eye by the light from mercury vapor lamps, they also appear more sharp in the ordinary photograph taken by this light, although for an entirely different reason. As pointed out recently by Dr. Louis Bell, the greater visual acuity in this case is due to the fact that the light is almost monochromatic. That is, the eye is not a perfect optical instrument, but is subject to chromatic aberration, the same as an uncorrected photographic lense, and the light rays from the opposite ends of the spectrum cannot be focussed at the same time. Thus a ray of white light cannot be focussed sharply in its entirety but the predominating color, which in the case of sunlight is yellow, is sharply focussed, while the other colors are not sharply focussed at the same distance from the lense. The resultant blurring is ordinarily so slight as to remain unnoticed, and its physiological effect is greatly reduced on account of the relatively greater intensity of the predominating color.

With a monochromatic light, all the light rays which enter the eye can be focussed sharply. Hence the greater ease and clearness with which small details can be seen with this kind of light.

Chromatic aberration cannot however, be blamed for any lack

of sharpness produced by a high grade photographic lense. In fact, a fully corrected lense will produce equal results, as far as sharpness is concerned, by any kind of light. Light which is rich in actinic rays does, however, tend to produce a greater degree of contrast in a photographic plate. This effect causes the details in the print, and especially in a half tone reproduction, to stand out more plainly, producing the effect shown in the first illustration in Mr. Clewell's article which is ordinarily, though incorrectly, called sharpness.

Bearing these facts in mind, it should be noted that Mr. Clewell in no case advances his illustrations as evidence that the installations are satisfactory. They are shown merely as examples of installations which have been found to be satisfactory by actual usage, and are presented in the belief that a photograph will show more as to the character of the surroundings and the conditions to be met, as well as the methods by which the results were accomplished, than could any detailed description. These points could be illustrated by photographs taken by daylight, as well as at night, and in fact one of them was taken by daylight. Most of the photographs were taken at night, however, in order to show the uniformity of the illumination, and the comparative freedom from glare, which is well brought out in the several illustrations.

CHAS. R. RIKER

STEAM TURBINES FOR ELECTRIC STATIONS OF MODERATE SIZE*

EDWIN D. DREYFUS

THE national trend toward securing efficient production in our industries has long since extended to the modern power station. And here may be found the most carefully planned and executed equipment, achieving not only the economic utilization of materials, but also the efficient application both of manual labor and executive forces. Quite logically, the larger stations were the first to institute these reforms, but now the smaller stations are following closely, and being governed by this same far-reaching influence.

It is very evident therefore that our present needs demand particularly such qualifications as are intrinsically possessed by the steam turbine, that is to say, the most direct conversion of available energy into effective power, which serves to eliminate all possible working parts and wearing surfaces, and thereby results in:—

1—Minimum attendance and supervision,

2—Least cost to supply, operate and maintain, and

3—Economy and convenience in space requirements.

The notable advances in the metropolitan stations in this country have been accomplished almost entirely through the large steam turbine. Not only has the steam consumption been greatly reduced, but these plants require only from one-quarter to one-third the engine-room operating force which would have been necessary for reciprocating machinery. Moreover, and virtually as important is the fact that maintenance expenses have been correspondingly lowered. Therefore, considering also the lower plant investment and fixed charges, the cost of producing power has been very substantially reduced.

While in the smaller stations the advantages of the turbine may not be present to as great a degree, it introduces other economic considerations that should effect an ultimate benefit to the small station comparable with what has been secured in the larger plants.

An adequate division of responsibility characterizes the organization of the large station, so that each and every part of the work is capably and thoroughly performed. The smaller companies are

*A paper read before the Mississippi Electrical Association, June 21, 1911.

not justified in employing a special engineering staff, such as is maintained by the larger stations, to investigate the performance of the equipment and thus guard against any avoidable decline in efficiency. In the small plant these duties devolve upon the manager or superintendent who, in many cases, has already assumed the responsibility for other departments of the business, including the executive and commercial branches, the neglect of which will, of course, seriously retard the development of the property. Consequently, the objective point should be to provide equipment insuring the greatest immunity from sources of trouble and derange-

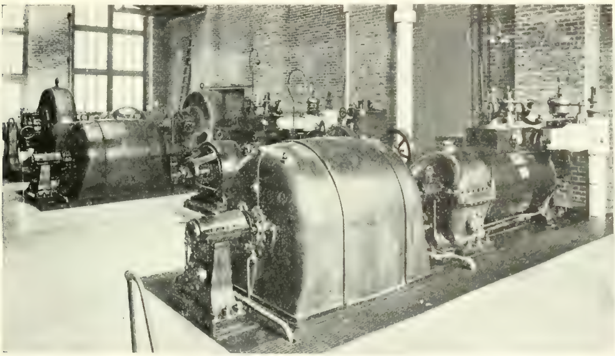


FIG. 1—PARTIAL VIEW OF TURBINE ROOM OF THE MISSISSIPPI AND GULFPORT TRACTION COMPANY (GULFPORT, MISS.)
Two 500 kw, 60 cycle units.

ment. These considerations not only explain, but form well-founded reasons for the growing popularity of the small turbine.

TYPES

The various types of steam turbines are now fairly well known. It may, however, be desirable to discuss them briefly to bring out a few salient facts.

Commercial turbines belong either to the so-termed *impulse* or to the *reaction* type or, as in some cases, combine the features of both. It is still found that the fundamental principles of operation thus designated, are too frequently confused. For example, in either design, the turbine actually combines the *action* and *reaction*

features. However, an accurate distinction may be made in the following manner:—In the true *impulse* turbine, all expansion takes place in the stationary nozzles, velocity energy thus provided being imparted to the moving blades. In the reaction turbine, the expansion occurs both in the moving and the stationary elements, transferring a small part of the energy by impulse at the entrance, and the remaining greater part by reactive thrust on the rotating blade at exit. It may easily be perceived that the steam, acting immediately upon the wheel as expansion takes place, will produce the highest economy, and the losses from nozzles to buckets are thus avoided. The best forms of reaction blading, such as the

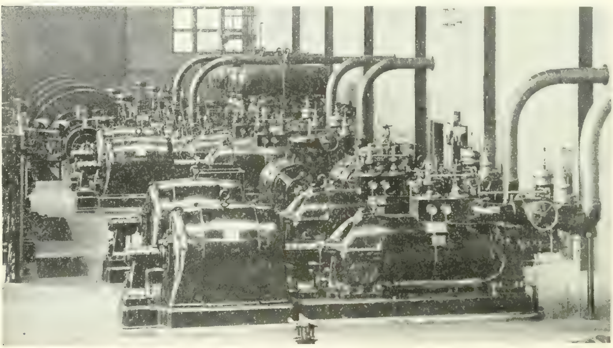


FIG. 2 POWER EQUIPMENT OF THE WASHINGTON TERMINAL COMPANY, WASHINGTON, D. C.

Four 300 kilowatt alternating-current units and air compressors.

Parsons, really constitute small nozzles in themselves and are, consequently, recognized to be of much higher efficiency than buckets. Nozzle and bucket efficiencies compare approximately as 95—98 percent to 75—80 percent.

In connection with the two turbine systems it is sometimes claimed that the discharge angles in one type may be greater than in another without any difference in efficiency resulting. The error of this statement, while not apparent at first may be shown vividly by the construction of velocity diagrams, proving that the exit velocity loss occurring in either case will be equally affected by the degree of discharge angle employed.

The Parsons turbine is the only design utilizing primarily the

expansion of steam in the rotating blades, while the Curtis, Rateau and Zoelly are familiar examples of the impulse type.

Another important feature is to be observed in the adaptability of Parsons blading to the drum type rotor, which constitutes a very rigid construction, favoring high rotative speeds. On the other hand, the multi-cellular impulse turbine must necessarily employ thin discs and shafts having a low critical speed. Larger shafts could be adopted for multiple impulse wheels, but the interstage gland and leakage problems would thereby become more serious. The single impulse wheel with multi-stage use of the steam, as more fully described later, is consequently to be favored. There

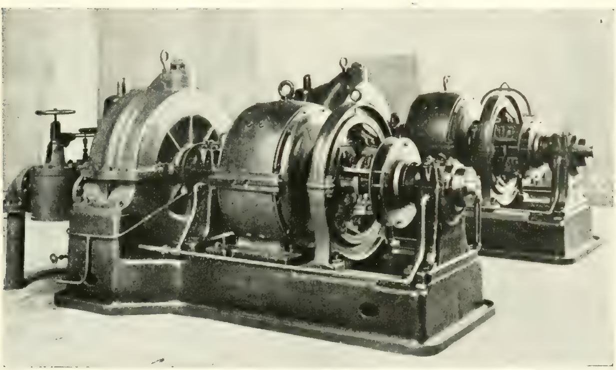


FIG. 3—TWO 100 KILOWATT DIRECT-CURRENT TURBINE UNITS
West Penn Railways Company, Connellsville, Pa.

are obvious cases where it proves best to adopt either reaction blading entirely, the straight impulse wheel, or a proper combination of both types, as hitherto noted, and which may be determined by size and working conditions. For large sizes, turbine records indicate that the Parsons design has not only established the highest thermodynamic efficiencies, but has also proven less subject to deterioration in economy in continuous service. This was brought out during the steam turbine discussion at the December, 1910, meeting of the American Society of Mechanical Engineers. A 10 000 kilowatt Westinghouse turbine developed 69 percent Rankine cycle efficiency under test and an important build of Parsons turbine abroad was recently reported as showing 68.3 percent on ef-

ficiency trial. Several tests of Westinghouse turbines, made immediately after installation, and also after a number of years operation and reported by excellent authority, showed no change in economy whatsoever. This may reasonably be expected from the fact that the relative steam velocities in this type are low, minimizing any erosive action, particularly in the low-pressure stages where the moisture content of the steam is high. Moreover, small wear of the blade edges is of no particular importance in this design.

Each of the various types cited above have had their advocates, and their predominance in some sections has been due to a great extent, if not entirely, to trade relations, rather than to any real underlying merits of design; and, if judged from the former standpoint, this ratio will, of course, tend to distort any estimate of their comparative merits. However, a fair impression may be had of their respective importance when a summation is made of the extent of turbine development, both in this country and abroad. From statistics, we find there exists to-day approximately *14 612 000* horse-power of Parsons turbines, and about *6 700 000* horse-power of all forms of the purely impulse turbine. This immense quantity of power represented by the Parsons turbine is aided in no small way by marine installations for various types of vessels. In this service the turbine is subject to the most exacting demands, and that the Parsons type has fully complied with the requirements, is forcibly shown by its rapid extension in this field, over 6 000 000 horse-power having been installed for marine propulsion. In fact its advantages have become so marked that a vast amount of energy has recently been expended in adapting it to marine work. And it is almost unnecessary to remark that its success inaugurates a new epoch in marine practice.

What has preceded applies mainly to units of moderate and large powers. The type of machine demanded for capacities less than 300 kilowatts is quite different, as the most elementary form of turbine is essential. In these small sizes, where the economy may be somewhat sacrificed, as the absolute steam quantities are of no appreciable magnitude, the simplest arrangement, using an impulse wheel, has been adopted. This situation bears a very close relation to the change from triple expansion pumping engines in large water works to direct-acting pumps for stations supplying only a small demand. Similarly the fields for the Corliss engine and the small automatic engines, have in general been quite

distinct, but naturally turbines do not necesarily have a corresponding line of demarkation.

The small turbine admits of wide departure in construction, and has, therefore, assumed a great variety of designs.* Their merits depend for the most part, if not wholly, upon the facility with which they may be adapted to specific requirements and the *ease with which substitution of various parts may be made.*

PARSONS TURBINES OF MODERATE SIZE

Construction—The rotor consists principally of three drums, Fig. 4, of varying diameter *R*, consisting of high, intermediate and

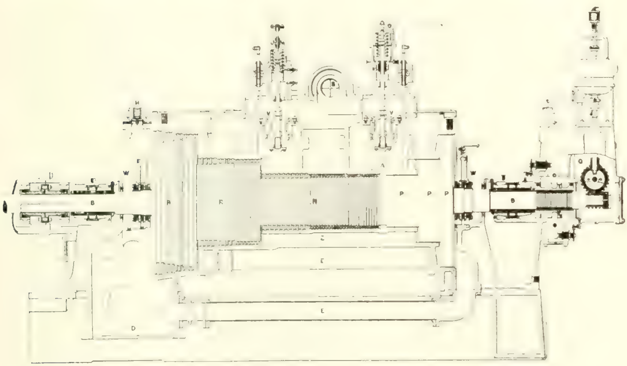


FIG. 4—SECTION OF TYPICAL SINGLE FLOW TURBINE

low-pressure stages which have all end thrust neutralized by counterbalancing pistons *P*. Pressures at various stages are communicated to the balancing pistons through equalizer passages *E*. In general, this section represents the usual construction of all Parsons turbines. There are, of course, some departures made in different builds, chiefly in the arrangement of balancing pistons. These, however, are of no importance in the sizes in which the construction here illustrated is mainly used. Two self-aligning high-speed bearings *B* are used. Steam is introduced at *S* and controlled by the main admission valve *V* (to the right) admitting to the annulus *A*. To provide for heavy over-loads, steam under full pressure is supplied

*Most of these were described by Mr. Geo. A. Orrok, in a paper before the American Society of Mechanical Engineers in 1909.

to the secondary valve *V* (to the left). A valuable provision is made to keep the governor valves in a constant vibrating motion, and in this way no friction of rest or sticking of the valves is to be overcome for any change in governor position. Thus the regulation of this turbine has always been above criticism. The exhaust passage is shown at *D*. Water sealing glands at *W* positively prevent any inflow of air to the turbine, which would obviously impair the vacuum.

The blading formation and construction is an important feature of the turbine, and these characteristics may be seen in Figs. 14 and 17. Probably no other detail of the design has been the subject of such extensive experimentation as has been accorded the blading itself. Various blade shapes and methods of securing them to the rotor and cylinder have been exploited since the early turbines were built. Blading sections and lengths are now made so as to effect an almost ideal expansion of the steam passing through the turbine. In attaching the root of the blade, the problem is remarkably simple, the blade being provided with a small nick in the root and held by the compression forces of the calked soft steel packing pieces. Under tension test, the blades will fail at some intermediate section before detaching at the root, due to the firm grasp of the packing pieces. Fastening of the blade tips has undoubtedly attracted the greater attention. Where there is a drop of pressure across each row of blades, it is preferable to maintain minimum clearances to reduce steam leakage. Some clearances may be actually beneficial to the economy of the turbine as it provides a passage for the water in the steam, permitting it to flow through without causing hydraulic friction on the tips of the moving blades, a theory advanced by experienced operators of steam turbines. A reinforcement of the outer ends is only necessary for long blades in order to avoid nodal vibration which might be set up by the steam currents, ultimately causing crystallization and failure of the blades. In the turbine shown in Fig. 4 this is accomplished by a "comma" wire lashing which, on being clinched, establishes a stout abuttment between consecutive blades.

Since the turbine cylinder has been made so symmetrical in design, distortion troubles have been removed. Protection on the tips of the blades is therefore, not only unnecessary, but on the contrary, the naked blade will cause the least injury in event of accidental contact due to any inaccurate adjustment, which is evi-

dently quite a remote possibility in this type of turbine. A ventilated and interrupted rubbing surface is presented, so that the least amount of local heating is produced, thus avoiding any serious damage. Shrouded blades were used as early as 1887, only a few years after the Hon. C. A. Parsons invented the turbine which bears his name. This was attempted primarily to reduce leakages, but any gains that may have resulted were more than neutralized by the increased skin friction. Shrouding is still used in some designs of Parsons turbines, but from actual figures, those thus provided represent not more than five and one-half percent of the turbines of this type.

It is indeed very gratifying to observe in connection with the early Parsons turbines built by the Westinghouse Machine Company (from 1896 to 1900) that no radical departure from the original design has been found necessary in capacities ranging from 300 to 1 000 kilowatts for the purpose of improving economies. Some detail changes have of course been made, principally in cylinder construction, to obviate troubles from distortion due to lack of symmetry. By relieving the cylinder of all unnecessary webs and the integral equalizer ports, the cause of the majority of the operating troubles encountered in the first machines has been entirely overcome. The construction which was thus developed to so satisfactory a stage many years ago and now so well known is shown for detail reference in Fig. 4.

A typical installation at the plant of the Mississippi and Gulfport Traction Company is shown in Fig. 1. A 1 500 kilowatt unit of the same type has been added since this photograph was made. Another interesting installation is given in Fig. 2, which shows the interior of the plant of the Washington Terminal Company, Washington, D. C. With all governor gear and valves above the cylinder, the arrangement adopted for these turbines, their operation is always in plain view; and with the accompanying ease of inspection, the attendance required for this extensive equipment is undoubtedly less than usually employed.

UNUSUAL INCIDENTS

There can be no question but that the intrinsic merits of any apparatus are always brought out more forcibly by unusual events in its history than by its ordinary operation. In this respect, the extreme simplicity of the turbine cannot be better demonstrated than by a case in which a 500 kilowatt low-pressure turbine of a

character later described, was placed in service by the customer's own engineering staff who, besides having never operated a turbine, had never seen one in service or even dismantled. The machine had operated one month before the builder's erecting engineer reached the plant to make an inspection. He found the turbine in excellent adjustment. It is of additional interest to note that this plant is at a distant Canadian point.

Another extraordinary occurrence is worthy of note. While en route to central Mexico, a car carrying a 1 500 kilowatt turbine was derailed and the machine thrown down a high embankment. It was necessary to build a special spur track to recover the turbine, and after being reloaded and safely carried to destination, it was found that with the exception of damaged lagging, the machine had sustained no injury.

The individual qualities of the turbine were also strongly emphasized in a disastrous fire which occurred in a certain station in the West. In this instance all inflammable parts of the building, including the roof and floors, the latter being thoroughly oil-soaked, were entirely consumed. The heat from this fire was so intense that it destroyed practically all of the engine room equipment, with the exception of the turbines, of which the valve gear, being exposed, was the only part to suffer. The reciprocating engines, which were alongside the turbines, were damaged beyond repair. The short time required to place the two turbines in service speaks for itself, the 500 kilowatt machine requiring ten days and the 1 000 kilowatt unit twelve days from the time of the fire. This included the time necessary to order new parts from the builder's works, 1 600 miles distant, three days being consumed in transit, and the time necessary for fitting up the machines and opening them for inspection, for which purpose temporary rigging was provided. Previous to this, the 500 kilowatt unit had been in operation night and day for 18 months without repair cost. Repair parts to the extent of $1 100 were carried in stock and lost in the fire. In all, the actual cost of repairing both units was about $2 000, which amounted to approximately five percent of their cost.

SMALL IMPULSE TURBINES

A new development, which becomes of especial interest, is an unique type of impulse turbine designed for the generation of small powers. It is mainly in this field that the greatest variations

in working pressures are usually found. Hence it is very important that the design admit of wide limits of application and at the same time involve the least changes in construction in order that it may be economically and commercially adaptable to fluctuating requirements. For a fixed capacity and rotative speed, proper dimensions of the rotor and cylinder (exclusive of the nozzles and reversing chambers) may be established in a large degree without definite regard to the actual pressure to be employed. Then for reasonable deviations from the customary pressures, it is necessary only to proportion and arrange the nozzles and reversing chambers to comply, a very small operation compared with work on the entire unit.

TABLE I—B. T. U. AVAILABLE BETWEEN VARIOUS INITIAL PRESSURES AND 15 LBS. AND ONE LB., ABSOLUTE.

Initial Conditions		Final Conditions	
Pressure. Lbs. Abs	Temp. Deg F	15 Lbs. Abs. Temp. 213° F.	1 Lb. Abs. Temp. 101° F.
		B t.u Available.	
105	331	142	294
125	334	157	306
145	356	166	315
165	366	177	325
190	377	186	333

From Peabody's Steam Tables—1909 Ed.

Steam pressures require closer consideration in turbine than in reciprocating engine design. Turbines utilize the energy of the steam through dynamic operation; i. e., the development of high velocities which are subsequently absorbed during the passage of steam through the rotating wheel. In the engine the expansive force of the steam is exerted directly upon the piston. It is well to keep this distinction in mind when gauging the merits of the small turbine. Through adiabatic expansion of steam between certain limits, there is a given amount of heat energy released. This heat energy is immediately converted into work upon a receding piston in the steam engine, as just mentioned, while in the turbine it is transformed into velocity energy, which may be shown mathematically in the following manner:—

Kinetic Energy $= H \times 778$ ft. lbs., where $H =$ Available B. t. u. If $V =$ Velocity of issuing jet in feet per second,—then $V^2 \div 2g = H \times 778$, or $V = \sqrt{2g \times 778 \times H} = 223.7 \sqrt{H}$.

In the ideal impulse turbine, the buckets should travel at one-half the steam velocity. In commercial practice, it may be necessary to depart somewhat from the ideal, and moreover, in order to simplify stage construction, it is desirable to transform the energy in the high velocity steam into mechanical energy in two or more steps with moderate blade speeds. As an illustration, Table I has been prepared to present a general idea of the amount of heat energy available per pound of steam between customary working pressures and temperatures.

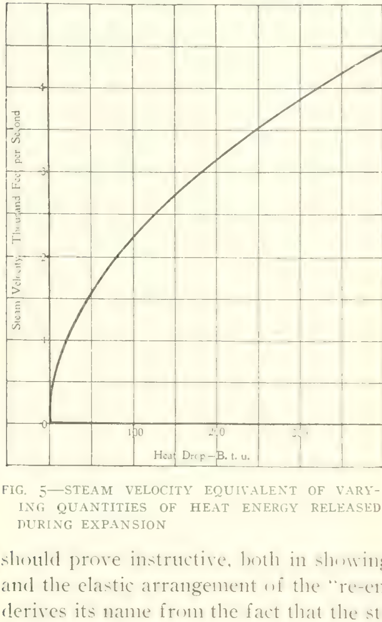


FIG. 5—STEAM VELOCITY EQUIVALENT OF VARYING QUANTITIES OF HEAT ENERGY RELEASED DURING EXPANSION

The variation in velocity developed by different heat drops may be appreciated from Fig. 5, and since the practicable blade speeds in small turbine work are at present ordinarilly confined between limits of 350 to 500 feet per second, the reasons for the divisions of pressure and velocity stages are evident.

Practical examples should prove instructive, both in showing the fundamental features and the elastic arrangement of the "re-entry" type of turbine, which derives its name from the fact that the steam issuing from the wheel is re-directed upon it again by reversing chambers as illustrated in Figs. 6 and 7.

Case 1—Working pressures of 100 lbs. initial and 15 lbs. final are assumed. This gives a heat drop of 130 B. t. u. As approximately ten percent is lost in nozzle friction, the resultant velocity acting upon the wheel becomes 2 400 ft. per second, Fig. 5. Taking a normal blade speed of 500 ft. per second and blade angles of 25 degrees, the steam velocity fixes the nozzle angle at 20 degrees. Reducing the relative velocity R_1 for blade friction, the relative

velocity R_2 leaving the wheel is found, thus determining the absolute velocity V_A. The magnitude of the latter shows why it is necessary to provide for repassage of the steam through the wheel. This steam is redirected upon the blades through the reversing chamber *B*, friction decreasing the absolute velocity to 1 200 ft. per second, establishing a nozzle angle of 15 degrees. Under these conditions the steam jet issues at right angles to the wheel with a small residual velocity of 250 ft. per second, thus reducing the loss from this source to a minimum.

Case II—Assuming now that the pressure range had been from 135 lbs. to 15 lbs. absolute, the steam is expanded from

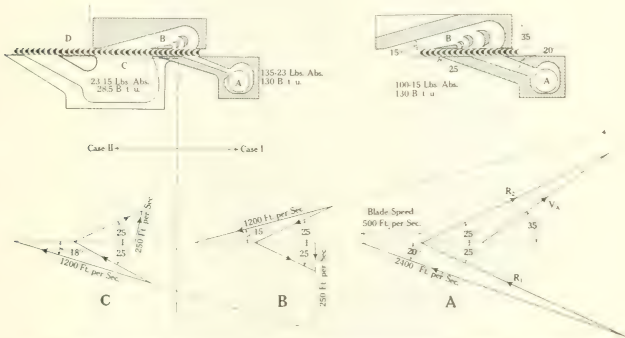


FIG. 6—PRINCIPLE OF NOZZLE AND REVERSING CHAMBER, WITH ACCOMPANYING VELOCITY DIAGRAMS

Case I—Pressure Range, 100-15 pounds absolute. One pressure stage, compound velocity drop.

Case II—Pressure Range, 135-15 pounds absolute. Two pressure stages, compound velocity drop in first stage and single velocity drop in second stage.

135 to 23 lbs. absolute in the first stage. The available heat would still be 130 B. t. u., and therefore, the velocity developed remains the same as above. Then the high pressure nozzle and reversing chambers *A* and *B* in both cases will be similar, excepting that in Case II they will be of less width due to the greater steam density. However, with the pressure of 23 pounds at the end of the first stage, a velocity of 1 200 ft. per second may be developed by further expanding to 15 lbs. absolute, which is accomplished by the addition of the nozzle *C*, Fig. 6. Had the initial pressure been higher, the residual velocity at *D* might have been sufficient to warrant the addition of another reversing chamber in the second stage.

Depending upon the pressures and speeds used a third stage may be profitably employed.

These diagrams serve to illustrate in a general way the methods used in the selection of various arrangements of nozzles and reversing chambers. It is, of course, understood that the size and details of the turbine may affect the choice considerably in some instances, and therefore, one may specify any one of the various

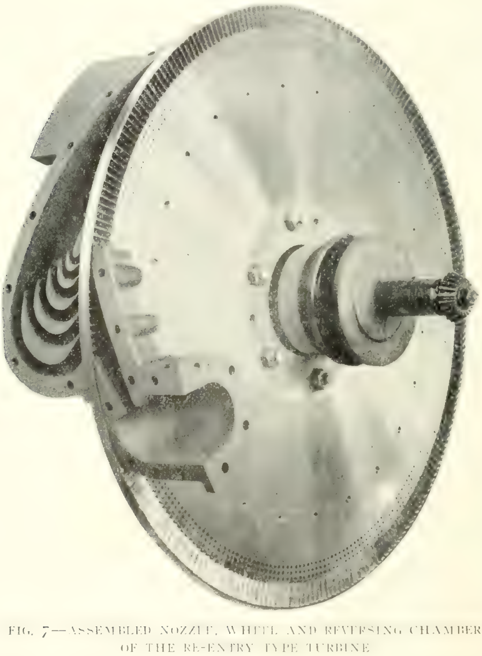


FIG. 7—ASSEMBLED NOZZLE, WHEEL AND REVERSING CHAMBER OF THE RE-ENTRY TYPE TURBINE

combinations on knowing all the particular characteristics of the turbine. Consequently this information is given simply to show that when the pressure conditions are accurately cited, nozzles can readily be provided that will result in very efficient turbines, and hence the exactness of the turbine construction will not be neglected, as no increased expense is entailed in ensuring its correctness.

A section through a 150 kilowatt, non-condensing turbine de-

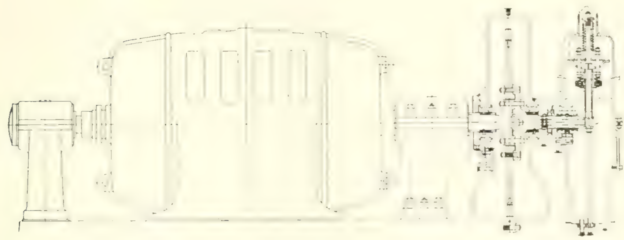


FIG. 8—SECTION THROUGH A 150-KILOWATT TURBINE DESIGNED FOR NON-CONDENSING OPERATION AND FOR DRIVING AN ALTERNATING-CURRENT GENERATOR

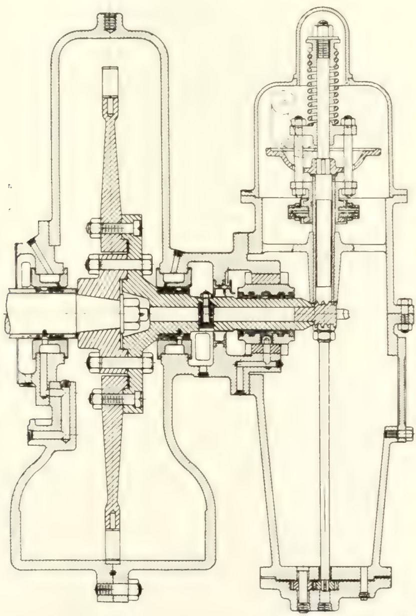


FIG. 9—DETAIL SECTION OF TURBINE SHOWN IN FIG. 8

signed to drive an alternating-current generator is given in Figs. 8 and 9. The flexible system afforded by the "re-entry" type may be said to be a direct result of the precedent established by the standard Parsons turbine in its ready compliance with working conditions, for instance, as accomplished in regauging; i. e., altering the relative angular position of the blading. The simplicity of construction realized in these small turbines may be observed from the sectional details, and therefore, requires little explanation. The rotor, comprising a flat steel disc with one row of blades mounted on the periphery, is carried upon an overhung shaft. A continuous shroud for the blades is established by having projections cast on

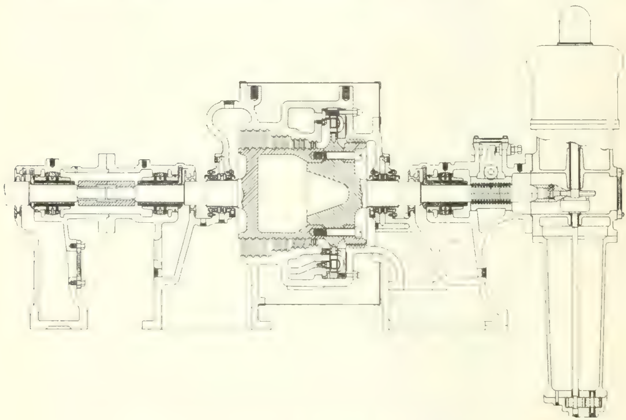


FIG. 10—DETAIL SECTION OF SMALL MIXED TYPE TURBINE

the back of each, to mesh with the face of the adjacent blade, which not only serves the primary function of maintaining the integrity of steam jet, essential in the impulse type, but also firmly braces the outer end of the blade, obviating any tendency to vibrate.

An additional bearing is provided on the governor end to steady the supplementary governor gear shaft, this being made detachable to facilitate dismantling. The cylinder is supported on benches forming an extension of the generator bed plate. This not only assures perfect alignment, but also eliminates any effect from temperature variations. Geared governors are used as they establish the highest degree of regulation. Forced lubrication is secured through the gear type pump which forms an integral part of the

turbine and results in a self-contained automatic unit. Oil under pressure reaches all surfaces in frictional contact. Protection against overspeeding is provided by an automatic stop.

MIXED TYPE

A composite impulse and reaction turbine was first designed in this country in 1902 mainly to accommodate large capacities, which innovation resulted in the successful development of the high-power double-flow turbine. In the small impulse turbine the economy for condensing work may be materially improved by the addition of a low pressure stage containing Parsons blading, as shown in Figs. 10 and 11. A number of turbines of this type have

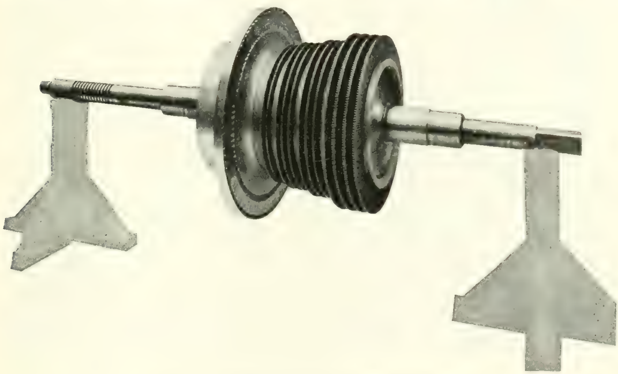


FIG. 11—MIXED TYPE TURBINE ROTOR

been built ranging in capacity from 100 to 200 kilowatts. This unit largely resembles in most of its details, the well-known Parsons type previously described, with the exception of the high pressure end. For this part an impulse wheel replaces the high pressure reaction blading, and is so designed as to efficiently absorb a large drop in steam pressure, or more correctly, heat energy. Incidentally, this same wheel is appropriated as a balancing dummy for the low pressure reaction end, which manifestly brings about unusual compactness. In this design, comparatively low blade speeds and steam velocities may be efficiently employed with the advantages of greatest freedom from the erosion resulting from the high velocity of moist steam jets, reference to which has previously been made,—

the cutting action varying approximately as the square of the relative velocity. Where fuel is costly, such a design, although more expensive, should prove fully warranted. It further exemplifies the versatility which is possible in turbine designing and is a type which has come into quite general use in Europe, where the fuel item is always the foremost consideration.

LOW PRESSURE TURBINES

The low pressure turbine will undoubtedly be found to be a benefit to the small reciprocating engine plant. In many of these

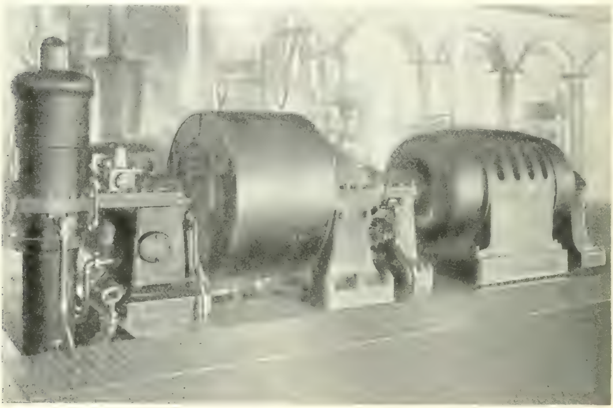


FIG. 12—100 KW MIXED TYPE TURBINE DRIVING 60 CYCLE ALTERNATOR
City of Alexandria (La.) Municipal Plant

stations the engines have been operated non-condensing for the reason that the expense connected with a condensing equipment would scarcely be warranted in view of the small return effected. Since the turbine works so efficiently in the low pressure ranges, station operators may safely expect to improve their plant economies from 30 to 100 percent through installing the low pressure turbine to work on the exhaust of their engines.

Such results are entirely practical and have been obtained, as in a typical case of a 500 kw low pressure unit installed for the City of Regina, Canada, where exhaust steam is obtained from one 22 by 30 inch Corliss and one 11 and 20 by 14 inch compound auto-

matic engine, governing being accomplished entirely through the latter units as the turbine is tied in electrically through synchronous alternators. The accompanying graphic charts, Fig. 13, show clearly that the fuel value has been practically doubled at the switchboard. Using the average figure given on the chart, it will be noted that the low-pressure turbine delivers 0.97 kilowatts per kilowatt of the engines. A fact developed in this station, as in many other low-pressure turbine installations is that no impairment of vacuum occurred

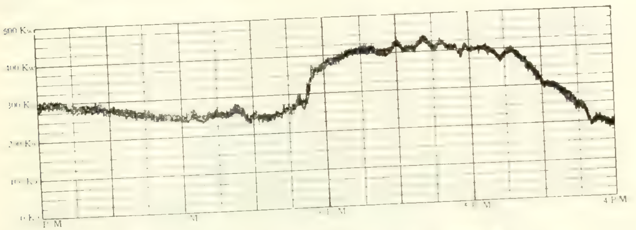


Chart from high pressure engines. Average steam pressure, 145 lbs. guage.

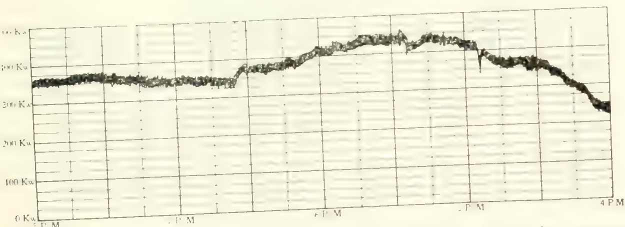


Chart from low pressure turbine. Inlet pressure 15 to 3 in. vacuum. Average vacuum 28.4 in.

FIG. 13—GRAPHIC METER CHARTS, CITY OF REGINA, CANADA

Showing station output practically doubled for the same fuel consumption through the application of a low pressure turbine.

due to the pressure in the piping between engine and turbine falling below atmosphere. As noted on the turbine load chart, Fig. 13, the inlet pressure varied from 3 to 15 inches vacuum, an average vacuum of 28.4 inches (30 inch barometer) being maintained at the turbine exhaust. Several advantages, both from the standpoint of efficiency and mechanical operation, accrue from allowing the pressure between engine and turbine to vary with load.

In a great many cases low pressure turbines warrant the use of cooling towers where an adequate cooling water supply is lack-

ing. Cooling systems may be arranged in various practical ways, and they generally add but a small percentage to the plant investment. They vary from being made of a pile of brush with suitable distributing troughs at the top, as pursued in some southwestern sections, or wooden lattice construction of open type, or spray nozzles either distributed over a cooling pond, or else as occasionally done, by appropriating the power house roof as a water shed, to the more expensive enclosed forced or natural-draft chimney coolers. These references are simply made to impress the fact that where small stations are unable to obtain a natural supply of condensing water, an effective substitute may thus be devised. In the design of cooling towers, free fall and excessive lift of circulating

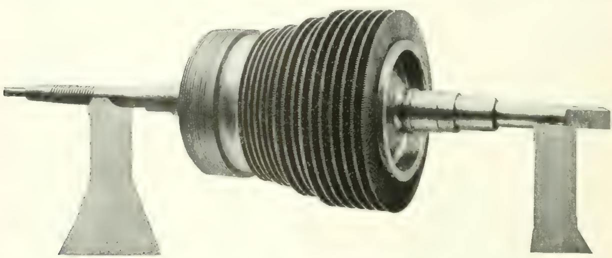


FIG. 14—SINGLE FLOW LOW PRESSURE TURBINE ROTOR
300 KW

water must be avoided in order that their operation may be most efficient.

Notwithstanding the high thermal efficiency that may be secured through using the low-pressure turbine, its installation is not to be indiscriminately recommended. It simply becomes a matter of economic consideration as to whether or not, at the load factor at which the plant is operated, the saving in fuel expenditure will be sufficiently in excess of the capital charges on the increased plant investment.

Generally the construction of the low pressure turbine is similar to that of the complete expansion turbine, excepting that the high and intermediate pressure elements are omitted. This is shown in Fig. 14 giving a view of a 300 kw Westinghouse low pressure turbine spindle. For small capacities, it would again be convenient and desirable to adopt the re-entry type.

BLEEDER TURBINES

Frequently central stations find it profitable to supply a heating load in addition to its electrical output. Previously in turbine plants, the low pressure steam was taken from the entrance of the intermediate stage and delivered to the heating system through a reducing valve. This method not only entailed considerable loss, but the amount of atmospheric pressure steam that could be bled, was unduly limited. To obviate this shortcoming of the standard condensing turbine, a special type of turbine has been developed, as illustrated in Fig. 15, in which the steam that passes from the inter-

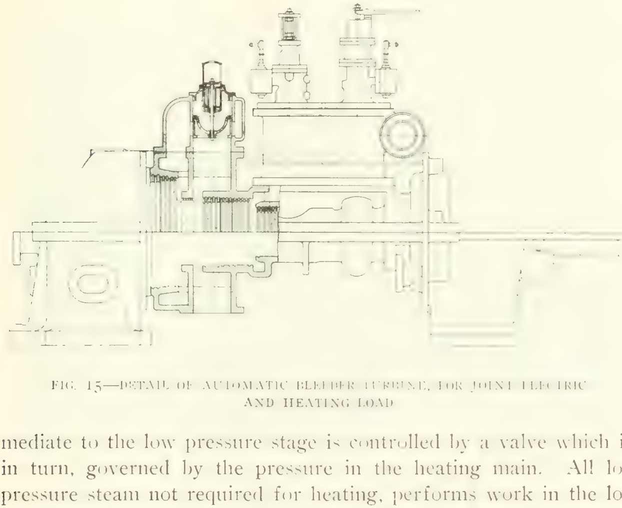


FIG. 15—DETAIL OF AUTOMATIC BLEEDER TURBINE, FOR JOINT ELECTRIC AND HEATING LOAD

mediate to the low pressure stage is controlled by a valve which is, in turn, governed by the pressure in the heating main. All low pressure steam not required for heating, performs work in the low pressure section, and besides, before the steam reaches the pressure of the heating system, it has been efficiently utilized in the high pressure elements of the turbine. When all of the steam is to be diverted to the heating system, the entire amount may, by special exterior piping, be made to pass through all stages of the turbine, thus obviously improving the economy.

OPERATION AND MAINTENANCE

Being entirely self-contained, the turbine requires minimum attention, and very frequently is given but little more care than an

electric motor. In fact, a central station owner visiting another plant, thought that the turbine driven centrifugal pump was electrically propelled. The absence of internal wearing surfaces such as in the steam-engine cylinder, prevents trouble from scoring and damage following a failure of the oil supply.

As there are no reversal shocks or strains in its operation, it is least subject to any disturbance of the correct adjustments. Therefore, the frequent applications of the indicator, taking up on pin bearings, resetting of valves and knock-off blocks, do not enter the operation of the steam turbine station. Further still, the turbine is

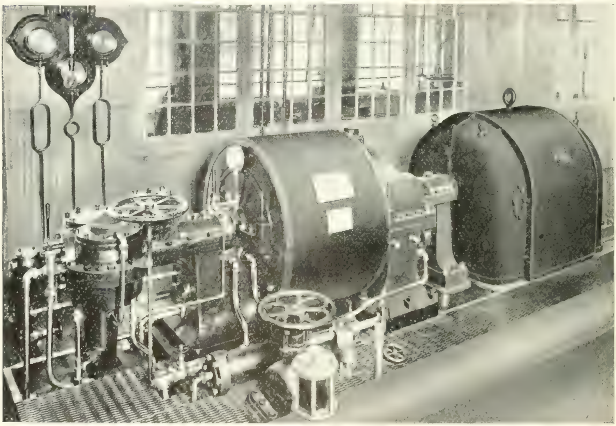


FIG. 16—300 KW LOW PRESSURE TURBINE WITHOUT GOVERNOR
Bernon Mills, Georgiaville, R. I.

immune from any damage due to "slugs" of water coming over with the steam, while with the reciprocating engine, precautionary measures must be taken to avert serious accident from this cause, by insuring that the cylinder relief valves are always operative. The exhaust is not contaminated with oil, and may, therefore, be safely used for any industrial application.

Bearing the above factors in mind, it is to be appreciated that the station force may be applied with the highest possible efficiency in a turbine equipped plant. The introduction of novel and valuable electrical appliances and the prosecution of new business campaigns,

requires the almost continuous attention of the management of small properties. With the greatest safety in operation of the power house equipment, *the management may well devote less attention to this part of the system and apply the time thus saved to a greater development of the company's service.*

That the turbine is capable of continuous operation over extended periods, has been demonstrated by actual performance. For example, a 500 kilowatt unit at the Quincy Market, Cold Storage and Warehouse recently completed a run of fourteen months without a stop and without any adjustments. While these long runs

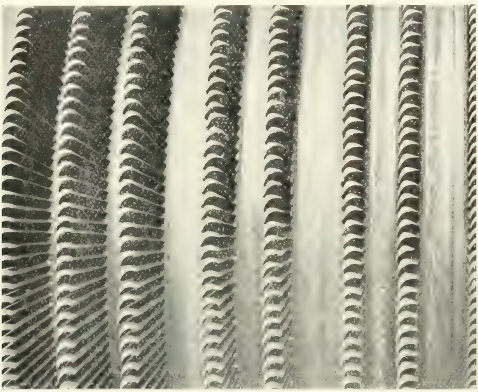


FIG. 17—CONDITION OF PARSONS BLADING AFTER SEVEN YEARS' CONSTANT SERVICE. ORIGINAL SHAPE AND QUALITY RETAINED

are of interest in showing the capabilities of the turbine, naturally the wiser policy is to provide for quarterly or semi-annual periods of inspection, as the case may require, unless unusual conditions may obtain. In the reciprocating engine, the attention which the valve stem and piston rod packing, piston rings, pin bearings and valve gear require, prohibit a similar performance.

When the subject of maintenance is considered, the question of local conditions must be given attention. Where there is a good quality of feed water, the turbine has usually been found to retain its original standard in service. But with water possessing any

active chemical properties, the cylinders have given evidence of erosion, and where steel blades were used, have required reblading in some cases, and, in a very few instances, reboring and relining of the cylinder. Original bronze blading which had been in service for nearly seven years in a 400 kilowatt turbine at the Johnston Harvester works at Batavia, N. Y., did not show signs of impairment, its present condition being evident from Fig. 17.

ECONOMIES

Several years ago a great deal of discussion was centered about the relative efficiencies of the engine and turbine. Actual tests have fully shown that the turbine excels for condensing service, bearing

TABLE II—TEST OF CORLISS COMPOUND ENGINE AT AMERICAN SUGAR REFINING CO.'S WORKS, BROOKLYN, N. Y.

Steam Pres. Gauge Dry Steam	Vacuum Ref. to 30 in. Bar	R. P. M.	Ind. Hp.	Mech. Eff. Percent.	Elect. Eff. Percent. Not inc. field loss	Equiv. Kw	Water Rate Lbs. per Ind. Hp—Hr	Water Rate Lbs. per Kw—Hr.	Lbs. per Kw—Hr.* Corrected to 100° Superht. & 28" Vac.
148	27.48	120.5	1004.0	95.0	93.9	670	12.75	19.16	17.8
149.8	27.98	120.9	853.3	94.3	93.8	562	12.33	18.7	17.6
149.9	27.64	121.2	819.6	93.9	93.8	538	12.55	19.1	17.8
151.3	28.26	121.5	627.4	92.0	93.3	403	12.10	18.9	17.86
150.1	28.33	121.9	491.4	90.0	92.8	311	13.92	22.35	21.15
150.1	28.16	122.6	339.7	85.3	91.8	200	14.58	25.0	23.3

*Correction Factors:—
Superheat—0.6 percent per 10 degrees F. change.
Vacuum—two percent per inch change of vacuum

out the general concensus of opinion. The curves, Fig. 18, may be taken to typify the comparison, where the turbine results were taken from U. S. Government tests and those of the engine as shown in Table II from tests conducted by Prof. D. S. Jacobus at the plant of the American Sugar Refining Company.* The much flatter economy curve of the turbine is in evidence. But, in considering economies on the whole, engineers should avoid simply comparing two types of units merely by test results or guarantees. *A factor for the de-*

*Published in the proceedings of the American Society of Mechanical Engineers, 1903.

cline in efficiency in service should always be introduced. Very little change in turbine economy will take place, especially where moderate steam velocities obtain, and its efficiency may be regarded as a practically constant quantity. This cannot be said of the reciprocating engine. Losses from leakages and poor adjustment of valves may, of course, be reduced to a rather small quantity. However, it is rare that they are entirely eliminated, and in this connection the following quotation from *The Engineer* may prove of interest:—

"Leakage past a solid plug or piston valve is a hard matter to determine, but that there is leakage is well known. The amount depends on many things; probably the first is the quality of the material of which the engine was built; the second, possibly, the accuracy with which the engine was built; and, thirdly, the care with which the engine is handled."

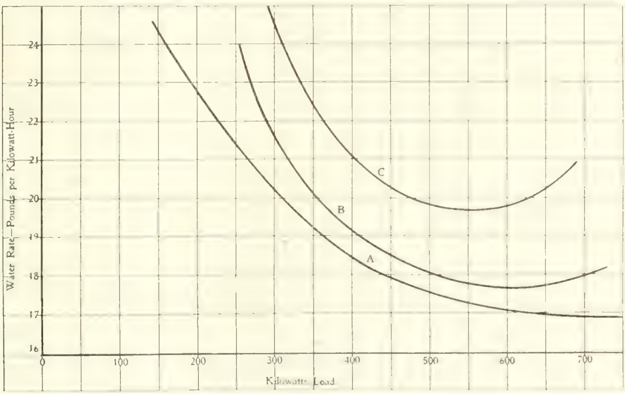


FIG. 18—CHARACTERISTIC ECONOMY CURVES OF ENGINE AND TURBINE

A—500 kw steam turbine at 150 pounds pressure, 100 degrees superheat, and 28 inches vacuum.

B—500 kw compound condensing Corliss engine at 150 pounds pressure, 100 degrees superheat, and 28 inches vacuum.

C—Average operating economy of 500 kw Corliss engine.

It is the extent of this deterioration in efficiency then, which may vary from one to ten percent or more, that concerns the power engineer. Such conditions are shown in the report of Messrs. Dean & Wood,* in which the fact was prominently brought out that the

*Before the American Society of Mechanical Engineers in 1908.

performance of practically all small engines was very much inferior to their rated efficiencies.

These statements are not intended as an arraignment of the reciprocating engine which, undoubtedly has been one of the potent factors in the early development of our industries. But many of its present drawbacks are so evident that they establish reason for its rapid supercession by the turbine. It is, of course, not to be gainsaid that the reciprocating engine of the highest type using multiple cylinders, steam jackets, reheating receivers, poppet valves in the cylinder head, and other refinements, have made noteworthy records. However, with ordinary working conditions and designs, a wide departure occurs from any such excellent operation, and this is becoming more broadly recognized, as indicated in a recent new engineering text book* which compares the best performance attained by different types of reciprocating engines with the average results to be expected in practice with the usual** good engine operating on reasonably steady loads. Operating conditions have been omitted, but manifestly it is the relative value of the two columns in Table III which bear the greatest significance.

TABLE III—COMPARISONS OF BEST STEAM RATE WITH AVERAGE STEAM RATE OF RECIPROCATING ENGINES USING SATURATED STEAM.

	Best Steam Rate Lbs. per Ind. Hp-Hr	Average Steam Rate Lbs. per Ind. Hp-Hr.
Simple Non-Condensing.........	21.50	38.00
Compound Non-Condensing...	19.14	23.00
Simple Condensing..............	16.50	22.00
Compound Condensing.........	11.22	18.00
Triple Expansion Condensing....	11.05	
Quadruple Expansion Condensing	(162.29 B.t.u. per min.; about 8.5)	

For non-condensing service, the small turbine is an extremely close competitor of the reciprocating engine, and when the inability of most engines to maintain their efficiency, is properly regarded, the turbine is fully on a parity, or may even surpass the engine. Partial data on economies is always unsatisfactory, as the working conditions of speeds, pressures and capacities, should invariably be considered, due to the marked influence they exert upon the results obtained.

Essential as it may be where the fuel supply is costly, the

*Applied Thermodynamics for Engineers, by Prof. W. D. Ennis.

**It should be borne in mind that in the book referred to, no distinction was drawn between automatic and four-valve engines.

heat efficiency of apparatus is plainly not the only governing factor in the selection of power house equipment. The cost to operate and maintain should also be critically regarded. Total operating cost of small stations averages as high as 2.5 cents per kw-hour or more, down to 0.6 cents or slightly less per kw-hour, including fuel, labor, oil, waste, supplies and maintenance. Evidently these figures depend upon size and type of equipment, cost of fuel, loading and other local factors, so that comparison may be misleading unless surrounding conditions in the two types of plants are very similar. While such data is usually rare, the following relationship between the turbine and high grade reciprocating engine layout obtained from the actual operation of stations of about 5 000 kw aggregate capacity in corresponding service, represents fairly well the economic influence of the steam turbine. With the engine costs taken as unity the comparative costs in the turbine station follow:—

Fuel	93	percent (high)*
Labor and Superintendence..	75.5	percent
Oil, Supplies, Miscellaneous..	23	percent
Repairs and Maintenance....	56	percent
Total Operation	85.7	percent

For smaller plants, these ratios should increase to some extent, but the overall results with the turbine will invariably remain superior. The foregoing percentages may fluctuate greatly, depending upon many factors, as the "personal" efficiency, age of apparatus, skill in operation (boilers in particular), etc., but invariably the turbine plant will be found the most profitable, not only from such immediate results as just cited, but also from the indirect causes previously defined. In a like manner we may treat of other forms of power machinery, but with stations of moderate size herein discussed, and coal not exceeding $3 to $3.50 per ton in cost, the best results are to be derived with the turbine equipment when both their aggregate running expense and capital account for the year are compared.

INSTALLATION

More striking than any other feature, is the exceedingly small engine room required to accommodate the turbine equipment. An extreme example has been taken such as would exist in a city office

*In the case of the engine plant, the individual loading on the units, which were greater in number, was more favorable to good economy than in the turbine station, which explains the apparently small improvement of this item with the turbine.

building where property and likewise the basement space possesses considerable value.

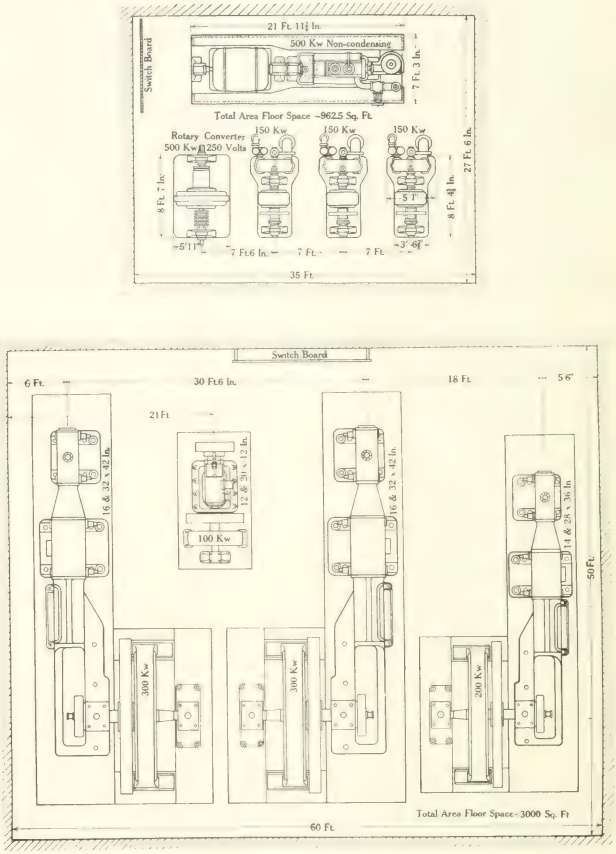


FIG 19—RELATIVE MINIMUM FLOOR AREA DEMANDED BY EFFICIENT NON-CONDENSING CORLISS ENGINES AND TURBINES, EACH AGGREGATING 900 KW

With an installation of tandem, compound reciprocating units of equal aggregate capacity, Fig. 19 (given preference over the cross-compound on account of space conditions), the floor area

requirements would be approximately three times that of the turbine equipment, in spite of the fact that a 500 kw alternator with a rotary converter was included for the purpose of supplying direct current when this might have been accomplished in a more direct way. Obviously the turbine contributes materially toward economy in the building and real estate investment. No restrictions are placed on the location of the turbines since heavy foundations to prevent vibration are not essential. Therefore, the turbines may be placed in accordance with the arrangement best suited to local conditions. They may even be carried on a structural support on a deck over the boiler room or other space, or else set up in the basement without fear of imparting vibration to the building. Due to its rotary motion, there are no pulsations in the turbine, rendering the use of foundation bolts unnecessary. The compactness of the turbine also facilitates its transportation and erection. Turbines of the sizes described, may be placed in service with unusual dispatch when received at the power station, thereby involving a minimum of time and expense for their installation.

ADDENDUM

This subject is manifestly so comprehensive that its many phases may be treated only superficially in the limited space of an article of this nature. In conclusion, therefore, it may be suggested that other contributions on turbines be consulted, and for a simple presentation of the theory and construction of the turbine, we would recommend the paper read by Mr. Francis Hodgkinson before the American Society of Mechanical Engineers (Chicago meeting, 1904), entitled "Some Theoretical and Practical Considerations in Steam Turbine Work," and his paper before the Engineers Society of Western Pennsylvania (1902) on "Steam Turbine, with Special Reference to Westinghouse-Parsons Steam Turbine." As to the economic value of the turbine, a review of its commercial aspect in a paper by Mr. E. H. Sniffin before the American Street Railway Association in 1902, is suggested. While these papers appeared some time ago, they are still as useful to-day as when first issued. For enlargement upon recent progress in design, the following papers by the author may be of interest:—

"Some Steam Turbine Considerations and Recent Efficiencies" (Engineers Society of Penn'a, 1910), The Electric Journal, March and April, 1911.

"Various Phases of Low Pressure Turbine Work" (Providence Assocn. of Mechanical Engrs., 1911), The Electric Journal, May, 1911.

"Present Steam Turbine Progress" (Railway Club of Pittsburg, 1910), The Electric Journal, August, 1910.

Edwin Musser Herr

EDWIN MUSSER HERR

A SKETCH OF CHARACTER

L. A. OSBORNE

Vice-President, Westinghouse Electric & Mfg. Company

THE selection of a new President by the Directors of the Westinghouse Electric & Mfg. Company is of more than local significance. The policies of an institution such as the Electric Company are matters of vital interest not only to the thousands of its employees but to the users of electrical apparatus the world over. On the soundness of its policies and the selection of the right man to lead the Company's destinies depends not only the welfare of the great army of employees but the continued economic advancement of the electrical art, in which the Company has been so long and actively engaged.

It is a matter then of more than mere ordinary curiosity which leads the world to desire to know something of the man who has been selected to head this important enterprise. A simple chronological statement, while significant of an individual's progress, fails to tell the whole story of a man and usually gives no insight into his personality, and it is the personality of the man after all which counts and it is that in which the world in general is most interested.

Edwin Musser Herr is fifty-one years old and his progress from the time that he was station master and operator at Deer Trail, Colorado, on the Union Pacific Railroad, in his early youth, through his college career at Yale, where he graduated as mechanical engineer in 1884, his apprenticeship, his increasingly important positions in railroad operation with the Chicago, Milwaukee & St. Paul, the Chicago & Northwestern, the Burlington and the Northern Pacific, his industrial connections with the Grant Locomotive Works, the Gibbs Electric Company of Milwaukee, the Westinghouse Air Brake Company, and as senior vice-president of the Westinghouse Electric & Mfg. Company, exemplifies in a striking degree the value of earnestness, devotion to duty and fair-mindedness, associated with an unusual talent for executive work.

It has been my privilege now for something over six years to be associated with Mr. Herr, during all of which time he has

been my immediate superior. It is but natural that during a period of such intimate contact, one should form well-defined opinions concerning the personal and intellectual qualities of the man. It is the experience of all to hear it frequently said that human nature, when viewed from the standpoint of intimate daily association, becomes commonplace and that the greatest men exhibit ordinary characteristics when seen at close range. Judged by the tests of daily, intimate association, Mr. Herr has signally failed to justify this cynical view of the world. Without effort, without any self-seeking, naturally and as a matter of the ordinary day's work, he has profoundly impressed his personality on the Company and to such an extent that his assumption of the highest executive office in its gift has been accomplished and accepted by everyone as a matter of course.

To him more than anyone have all looked for guidance during the trying period of stress through which the Company has passed in the last few years, and to his sanity, good judgment and foresight can largely be attributed the success with which the Company has emerged from its difficulties.

If I were to be asked what particular qualities characterize Mr. Herr, as differentiating him from the ordinary run of men, I should have to reply that there are many: First—his sense of duty is a prominent characteristic; his devotion to work is a tradition among Westinghouse employees; hours count for nothing if they can be devoted to the upbuilding of the interests of the Company. He is among the earliest at work in the morning and of the last to leave at night, and the intervening day's work is devoted systematically and continuously to constructive work. He seems to have in an unusual degree the proper balance between the important and the unimportant and yet no details are too complex for him to master if, in his judgment, it is important that he should do so.

Another important characteristic of Mr. Herr is his coolness and poise. In the most trying situations he is a fly-wheel to all of those about him. His judgment is never warped by exhibitions of impatience or temper. In all of my six years' association with him, I have never seen him lose his temper and the occasions which would have justified it have been many.

With all Mr. Herr's earnestness, singleness of purpose and poise in the many difficult, trying and annoying problems with

which he is called upon to deal, a refreshing phase of his character is his sense of humor. He is quick to detect the ridiculous and amusing in situations that are overstrained and that sense of humor I have often seen come to the rescue when it was most needed. He not only sees the humor in situations applying to others but will laugh just as heartily when the joke is on himself.

There is one quality which he possesses, however, which transcends all others and which leads men to follow him and that is his sympathy and fairness. This quality of sympathy for others in him is best illustrated by the constructive, continuous and systematic interest he takes in the educational work of the younger men and in his efforts to better the conditions of employment.

In all the difficult questions that he has had to decide as between man and man in the large organization of which he has been the head, I have never yet heard anyone say that he was unfair or had ever done any act which could be construed as indicating favoritism or bias.

I believe it to be the unanimous judgment of his subordinates that his selection for the high post of President of the Company is the right and proper one and that his personal qualities are such as will insure him the united and sympathetic support of every man under him, while his great experience and ability will inspire all to follow his leadership.

I appreciate that in being asked to write a short personal sketch of Mr. Herr, it is extremely difficult to strike the proper balance between fulsome praise and what might appear to be a cold analysis of character. Good taste on my part should relieve Mr. Herr of the embarrassment of having things said of him which would offend his modesty, for he is a modest man in the best sense of the term, but I am sure that these few statements of what appear to me to be the salient qualities of the man will find a strong response in the heart of everyone who has been privileged to know him intimately.

EFFECT OF STARTING CURRENTS ON POWER CIRCUITS

J. W. FOX

THERE has been considerable discussion at various times as to the effect of the starting currents of squirrel cage motors on power lines. In some cases transmission companies have prohibited squirrel cage motors above a certain size from being connected to their circuits, the claim being made that the large starting currents taken by such motors at a low power-factor affected their voltage regulation to a serious extent. Tests to determine the effect of motors of this type have been made in various plants and the charts here given show graphic recording meter records, both wattmeter and ammeter which represent the regular starting conditions in two large cotton mills. The voltages were checked by the aid of indicating meters. The graphic readings were also checked by both switchboard instruments and portable test meters, all of which agreed within a very small percentage.

The chart shown in Fig. 1 was taken in a cotton mill using secondary* power. It is of 25 000 spindle capacity and has a total motor equipment of 1 000 horse-power. The motors are three-phase, 60 cycle, 2 200 volts of the following sizes,—one 30 hp; one 50 hp; seven 75 hp and four 100 hp. It may be seen from the chart that the full or normal running load during the day is approximately 700 kw at an average power-factor of about 74 percent. From Fig. 1 it may be seen that the motors were started at 5:55 A.M. and that it took about 15 minutes to get all the motors running; the mill machinery was then started by the machine operators as the whistle was blown at 6 A.M. The load early in the morning was 750 kw (2 358 volts and 88.3 percent power-factor) while the ampere readings of the same hour show about 208 amperes (850 k.v.a.).

The momentary starting peak is only about ten percent greater than the normal operating condition which is about 640 kw at 73.5 percent power-factor, 228 amperes per phase at 2 200 volts, (870

*Secondary power may be cut off at the discretion of the power company in times of low water. The rates are cheaper than for primary power which is guaranteed continuous service. See the JOURNAL for April, 1911, p. 351.

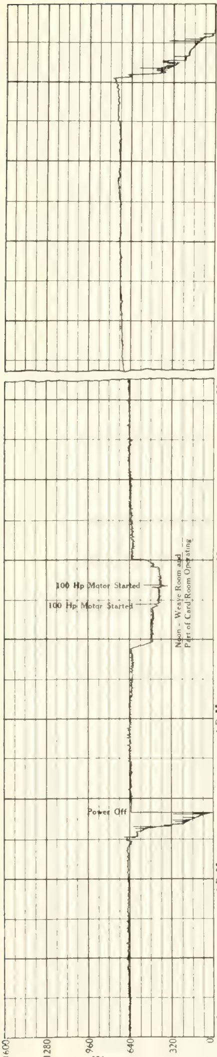


FIG. 1—POWER CURVE FROM A COTTON MILL HAVING 13 SQUIRREL CAGE MOTORS AGGREGATING 1 005 HP. THE CHARACTERISTIC DROPPING OFF OF THE POWER AS THE BEARINGS GET WARM IS PLAINLY SHOWN

k.v.a.). The peak is caused by starting the 100 hp motors. Between 12 and 12:30 P.M. the weave room is operated, also some parts of the card room; the chart shows the starting of two 100 horse-power motors in the spinning room for cleaning or other purposes, the main load gradually going on at 12:30 P.M. The starting conditions shown each day are essentially similar.

The next portion of the chart shows a peculiar condition and yet one that is liable to happen with any public service plant. Here the power was cut off at the generating station, the result being that the entire load throughout the system was momentarily dropped. When a condition like this arises it is customary for every consumer to do his best to get his plant in operation again as soon as the power is available, and it is during such times that the generating station is taxed the heaviest. Ammeter readings taken at this time show that the momentary ampere peak was only about 22 percent greater than the normal load in amperes. The power plant behind this mill had a capacity of about 100 000 horse-power, the transmission lines operating at 44 000 volts, with the main generating station about 60 miles away.

The cotton mill referred to above was originally designed for steam drive. Motors were later installed on the "group system". The old shafting and belts have

been retained so that in case of failure of the power plant or cutting off the power at periods of low water it could return to the steam mechanical drive. The shafting load under conditions like this is necessarily greater than if the mill had been laid out for electric drive. All motors are of the squirrel-cage type and are started from double-throw or two-point automatic circuit breakers, through auto-transformers, on a 65 percent tap.

The chart shown in Fig. 2 was taken in a mill of approximately 40 000 spindles, having a motor equipment of 1 350 horsepower. The motors were three-phase, 60 cycle, 600 volt machines varying in size from 50 to 100 horse-power. The order of starting the motors, as clearly shown on the chart, is as follows:—

Weave Room	75,	100 100 and 75 hp motors.
Card Room	100,	75, 100 and 75 hp motors
Spinning Room ..	50,	100, 100, 100, 100 and 100 hp motors.

The highest peak at starting shows 960 amperes, while the normal running load is 1070 amperes, or about nine percent less for starting than operating. Thirteen minutes was consumed in starting the motors. About fifteen minutes past 6 A.M. one of the 100 hp motors was shut down and started up two minutes later. The momentary peak is about ten percent higher than the normal ampere line; and this motor took about two and one-half times its rated full-load current to start. The power-factor at the instant of starting the motors listed above is about 60 percent, the kilowatts being 54 percent of the normal load. Another way of stating the same fact is that the starting k.v.a. is 915 or about 200 k.v.a. less than the normal.

The power plant behind this installation consists of 2 600 kw in generator capacity, three-phase, 60 cycles, and transmission lines of 11 200 volts, six miles long. Current is stepped down at the cotton mill from 11 200 to 600 volts.

A comparison of the charts taken from the two mills shows that the starting conditions of the first plant as compared to the operating conditions are more severe on both the transmission line and the generators than those of the second. The difference is due to the fact that the second mill was designed for electric drive and amount of shafting used is a minimum.

Altogether the foregoing charts show in a very clear manner that a power company or central station delivering current to a cotton mill equipped with large squirrel cage motors has

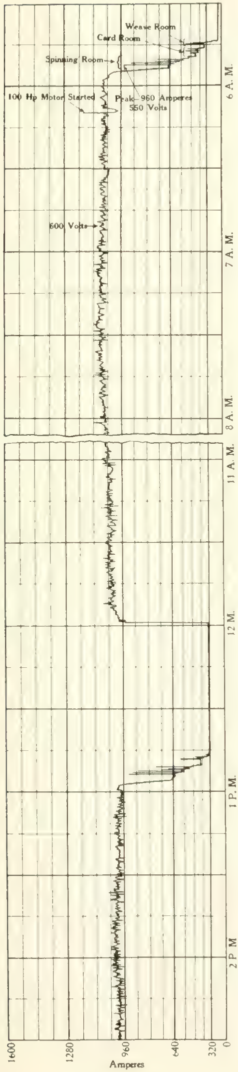


FIG. 2—CURRENT CURVE FROM ONE PHASE OF THE LINES FEEDING A COTTON MILL HAVING 15 SQUIRREL-CAGE MOTORS AGGREGATING 1 350 HP. THE MOTORS ARE STARTED UP WITHOUT LOAD, AND THE MACHINES ARE STARTED BY MEANS OF CLUTCHES

nothing to fear from the current required to start such motors. It is plainly shown that the current during the starting period in such a case does not materially exceed the current drawn from the line for normal operation.

The same result might have been anticipated by making a careful analysis of the conditions. In one of these mills the size of the maximum motor is about ten percent of the total motor capacity and in the other less than eight percent. A squirrel-cage motor takes two and one-half to three and one-half times full-load current from the line during the short interval of starting. The interval of starting one of these motors is a very short one and the period during which excess current is drawn does not, as a rule, exceed five seconds. After the motor commences to speed up the current required to operate it drops rapidly. The current, therefore, to start a motor which has a capacity of ten percent of the total equipment of the mill will be not more than 25 to 30 percent of the total current which the mill will require when operating at full load; moreover, this starting current is taken for a very short period. It would be necessary, therefore, to start three or four such motors simultaneously before the full-load current of the mill could be exceeded during the starting period. Since the large current flow is demanded

by the motor during the starting period for so short a time it is highly improbable that so many motors could be started at once as to cause the current at starting to exceed that for running during the normal operating period.

It is true that the above view does not tell the whole story. As more and more motors of a given mill are started up, the power taken from the line due to the loads which these motors take, is constantly increasing. As the last of the motors are started up, the starting current of these motors is added to the current which is demanded by the running condition of the motors already started. Therefore, the starting conditions as the last motors are placed in operation are more severe than those when the first motors are started. However, it is customary in cotton mill practice, as in many other lines of work, to start the line shafts first, the individual machines being started up later by loose pulleys and belts.

An inspection of Fig. 1 shows that when the individual machines are started the power taken by the motors is increased about 50 percent. In other words, the mill when run without the individual machines being in operation requires approximately 50 percent of the amount of power which is actually demanded when all of the individual machines are in operation. The worst condition in starting, therefore, would be when the last two or three motors are being started. Under these conditions there would be a power demand due to the motors already running of 40 to 50 percent of the total normal demand of the mill. To this would be added the starting current demanded by the last motors starting. If the last two motors, each demanding 25 to 35 percent of the normal operating current for the mill, were to be started at the same instant, the total current required would only slightly exceed the total current demanded to operate the mill under normal conditions.

It is exceedingly unlikely in any mill that more than two motors will be started and demand the heavy starting current at exactly the same instant. This follows from the consideration that the time during which there is a large current demand by the motors during the starting period is an exceedingly small proportion of the total starting period. The final conclusion which is manifest from the above charts and analysis is that the prejudice in the minds of many power companies against the use of squirrel-cage motors on account of starting difficulties is largely unfounded.

POWER HOUSE LIGHTING

C. E. CLEWELL

AMONG the most important requirements of power house lighting are reliability at all times and such a distribution of the light that all parts of the machines may readily be seen, with as few shadows as possible. In the engine room, valves, gauges and switch-board instruments must be adequately lighted, but a general illumination from lamps mounted overhead is of equal importance, so that the entire floor space shall be suitably lighted. There should be no difficulty in getting around the various machines and a general illumination over the entire floor will go far toward promoting rapid and efficient work during times of emergency and repairs.

In overhauling the steam and electrical equipment it is desirable that deep openings in and around the machinery be sufficiently lighted, and it will further be found highly desirable to provide an adequate amount of side light, for the purpose of properly illuminating the sides of apparatus, which under the ordinary methods of lighting will often be found to be in comparative darkness due either to an insufficiency of the side component of the light or to marked shadows.

ECONOMY AND IMPORTANCE OF GOOD LIGHT

Among the elements which promote the successful operation of a central station or power house are adequate and reliable steam and electrical equipment, a suitable arrangement of the machinery, coal and water facilities, ventilation, and artificial lighting of an intensity, quality and distribution to aid in the operation of the plant during dark days and at night, and to facilitate repairs and emergency work at those times when artificial light is imperative. The central station, therefore, usually looked upon as the source from which light and energy may be derived by the public, requires light of suitable quality in the economy of its own operation. A prolonged shut-down, due to accident or otherwise, involves more inconveniences and losses of time and money perhaps than a similar accident in any other industrial enterprise, and no element of the equipment should be overlooked in attempting to secure that continuity of service which makes for reliability and satisfaction as far as the consumer is concerned.

In like manner power plants associated with large industrial concerns are the source, not only of the artificial light for the factory, but also of most, if not all, of the motive power, and here again continuity of service, where perhaps thousands of workmen are dependent on the motor driven machinery, is of utmost concern, especially when it is considered that in some industrial plants a shut down of several minutes involves losses of hundreds of dollars in lost wages. Such losses must be chargeable to the power house and should be avoided by the station superintendent in every way possible.

A NEW VIEWPOINT

In the past the subject of power house lighting has received but little intelligent attention and the two-fold object of this article is first to indicate the progress which has been made towards securing more economical and better lamps, and second to point out some of the principles of installation which result in far more effective light than has been realized in the past.

FIG. 1—TYPICAL BOILER ROOM SHOWING THE EFFECT OF COOPER-HEWITT LIGHTING AT NIGHT

Note the excellent distribution of light on the front of the boilers.

Specialists in this field and the public generally are coming to an understanding of what good light involves, and new lamps and accessories are now being applied to secure these results. In a great degree the new science of illuminating engineering and the accompanying practical application of illuminating devices have been advanced by the introduction of such lamps as the Nernst, Cooper Hewitt, metallized filament, tantalum, tungsten, metallic flame arc, quartz mercury vapor, and the Moore lamp, all products of the last few years. This advancement has been largely influenced

by the fact that whereas ten years ago electric lighting was limited either to very small or very large lamps, such as the carbon filament lamp on the one hand or the arc lamp on the other, new possibilities are now presented in all branches of the lighting industry, since a variety of types of medium candle-power lamps are to-day available.

RELATION TO EFFICIENT OPERATION

The operation of a power plant consists in the routine attendance on the machinery, such as oiling, cleaning, starting and shutting down of machines, and reading gauges and switchboard instruments. In carrying on this routine work the prompt detection of trouble is important. Good light will be an aid in this direction.

FIG. 2—POWER HOUSE LIGHTED BY LAMPS WHICH ARE RATHER LARGE IN COMPARISON WITH THE MOUNTING HEIGHT

The effect of large lamps widely separated is to produce marked shadows and a poor distribution of light. This illustration shows the importance of adequate light at the time of making repairs. Photograph taken at night.

Those who have studied the problem of power house operation under conditions of inadequate artificial light will appreciate the difficulties involved. Repairs to apparatus, changes in wiring, rearrangement of machines, are all items which call not only for adequate light but also for light of suitable quality in the matter of direction, diffusion and the absence of glare, so that everything connected with the work in hand can clearly be seen. Work of this kind, where the illumination provided by lamps mounted overhead is poor, must be done by the aid of extension lines equipped with

carbon filament lamps, resulting in delays. Plenty of illumination from overhead lamps permits rapidity of motion and facilitates repair and emergency work.

LOCATIONS INVOLVED

Boiler Room—A reference to Fig. 1, indicating a typical boiler room, will show the nature of such a location. A narrow passageway is faced on one or both sides with boilers, and the gauges, piping, stoking apparatus and valves require moderate light. Satisfactory operation requires:—1—Adequate light for gauges and

FIG. 3—LARGE POWER HOUSE IN WHICH COOPER HEWITT MERCURY VAPOR LAMPS HAVE BEEN PLACED ALONG THE SIDES OF THE ROOM

This arrangement provides excellent side light, and where there are no high machines or other apparatus on the floor, the lighting is also fairly good at the center of the room. Obstructions, however, cast shadows due to the location of the lamps. Photograph taken at night.

valves; 2—Sufficient general light in the aisle for firing and cleaning the furnaces and for ordinary attendance; 3—Some side light on the front of boilers and furnaces; 4—No glare.

Basement—The basement usually has a low ceiling and is crowded with pumps, condensers and other accessories. The apparatus sometimes extends from floor to ceiling, making the lighting somewhat difficult. The dampness in the basement calls for special precautions in the installation of wiring and lamps. On ac-

count of the crowded condition of the machinery and low ceilings, numerous small units should be used.

Coal Bins and Conveyors—Where automatic stoking is employed the coal bins are placed above the boiler room, and must be accessible for inspection and some attendance. The passage-ways through which the coal conveyors operate should be lighted judiciously. Lighting in locations of this kind is important not only as an aid to workmen but as a safeguard against accident. The lamps should be so located as to be safe from accidental breakage.

Engine Room—Typical engine rooms are shown in Figs. 2, 3,

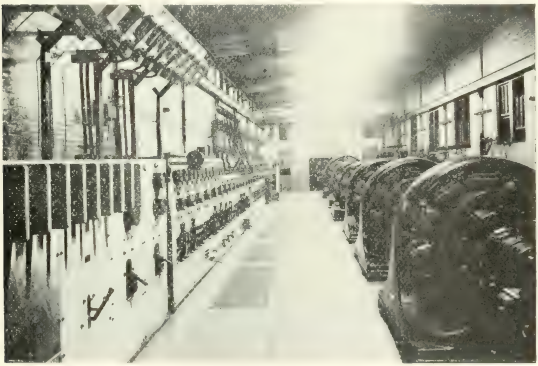


FIG. 4 A SUB-STATION IN WHICH COOPER-HEWITT LAMPS HAVE BEEN USED TO GOOD ADVANTAGE

Note the excellent light on the front of the switchboard as well as on the sides of the machines and on the floor. Photograph taken at night.

5, 6, 10 and 11. From these illustrations it will be seen that the floor space is usually filled with machines, and furthermore that any portion of the floor space is subject to use for repairs. The illumination requirements are 1—Sufficient general light for attendance and repairs; 2—Switch control so arranged that general lighting may be made moderate for ordinary purposes and increased for emergencies and repairs; 3—Adequate side light; 4—A sufficient number of medium sized units to furnish light in many directions, thus reducing marked shadows; 5—No glare; 6—Absolute reliability of the light at all times.

CLASSIFICATION OF POWER HOUSE LIGHTING

The various locations associated with the average power house present features more alike in general characteristics than is the case, for example, in factory lighting. The engine rooms nearly always involve the lighting of a large room filled with individual machinery; the boiler rooms are similar to one another; and the problem can, in the main, be presented in the form of a typical case which will contain the elements of successful power house lighting.

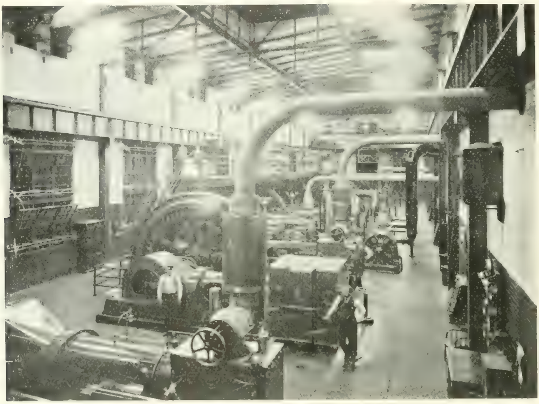


FIG. 5—POWER HOUSE IN WHICH COOPER-HEWITT LAMPS HAVE GIVEN SATISFACTION

Note the excellent distribution of the light afforded by this arrangement of the lamps and compare with Fig. 3. Photograph taken at night.

With slight modifications and good judgment, the adaptation of the principles and facts thus set forth may aid in designing systems of illumination for other locations of this kind.

TYPICAL POWER HOUSE LIGHTING PROBLEM

As a typical example of power house lighting in which the principles of successful illumination are found, a power house will be considered, which contains an engine room of about 10 000 square feet of floor space, and in which a satisfactory installation of medium sized lighting units has recently been made. This power house consists of an engine room, a plan and elevation of which

are shown in Figs. 7 and 9, a boiler room, coal bins and conveyor, and basement. The walls and ceiling of the engine room are light in color; the height from floor to ceiling is 24 feet and the room is divided into bays 16 by 76 feet, on the average.

This room was originally equipped with six enclosed arc lamps spaced about 32 feet apart and mounted 21 feet above the floor. The arrangement was equivalent to about one lamp for four 16 foot bays or about 0.4 watt per square foot of floor space. The arrangement of lamps as found is shown in Fig. 8 where the arc lamps of

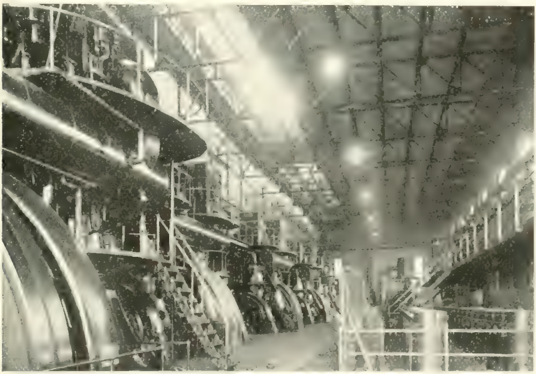


FIG. 6—ILLUSTRATION OF THE ARRANGEMENT OF HIGH CANDLE-POWER LAMPS OF THE METALLIC FLAME TYPE IN A LARGE POWER HOUSE WITH HIGH CEILING.

Photograph taken during the day.

the original installation are indicated by circles. The complaints from this lighting were as follows:—

1—The general illumination furnished by the overhead lamps was so poor as to cause difficulty in the ordinary work of attendance on cloudy days and at night.

2—The small number of lamps widely spaced produced marked shadows and required the use of extension lines for repairs on the apparatus.

3—The lamps flickered at times, due to voltage conditions, the lamps being supplied from the regular service mains.

FINAL ARRANGEMENT—As a result of this investigation the following changes were made:—

Boiler Room—Individual carbon filament lamps were installed over gauges and valves, and general illumination was provided by enclosed arc lamps located in the center of the passage-way between boilers. The light thus provided of moderate intensity was found to be sufficient for the class of work involved.

Basement—100-watt tungsten lamps were installed in some of the more open portions of the floor space and numerous carbon

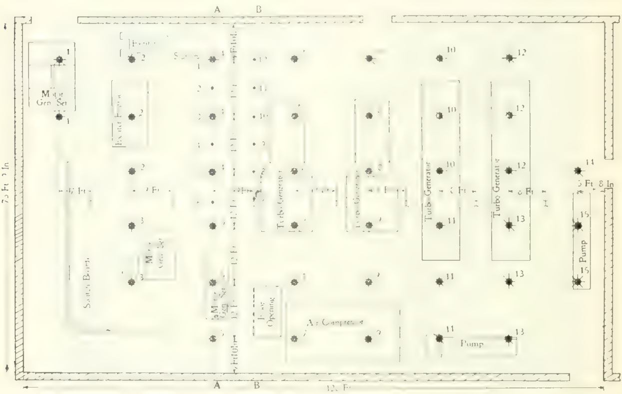


FIG. 7—FLOOR PLAN OF A TYPICAL POWER HOUSE ENGINE ROOM

Showing the arrangement of machinery and lamps. The curves showing distribution of the light in Fig. 10 are plotted from observations taken along the dotted lines *AA* and *BB*. Specifications:—40 250 watt clear tungsten lamps; 40 Holophane reflectors; lamps mounted so as to hang even with under side of girders. The numeral *1* adjacent to two lamps indicates that they are controlled from one switch, the numeral *2* adjacent to three lamps indicates that they are controlled from a second switch and so on.

filament lamps were located over pumps, valves, condensers, and other accessories.

Coal Bins and Conveyors—Carbon filament lamps were distributed throughout the bins and conveyor passages, thus providing a general light of moderate intensity. A slightly higher intensity may, however, be warranted in locations of this kind, furnished by lamps somewhat larger than the carbon filament lamps; for example, 100-watt tungsten lamps may be used to advantage mounted high and out of the way.

Engine Room—The first step in making up the lighting plans was to provide for adequate light by the use of numerous medium sized lamps. 250-watt tungsten lamps were installed as shown in Fig. 7 and also by Figs. 10 and 11. A reference to Fig. 8 will indicate the relative spacing of old and new lamps. The use of 250-watt tungsten lamps in this engine room as shown in the plan, provided the following:—

a—Uniform illumination over the entire floor space, with a maximum of downward, together with sufficient side light.

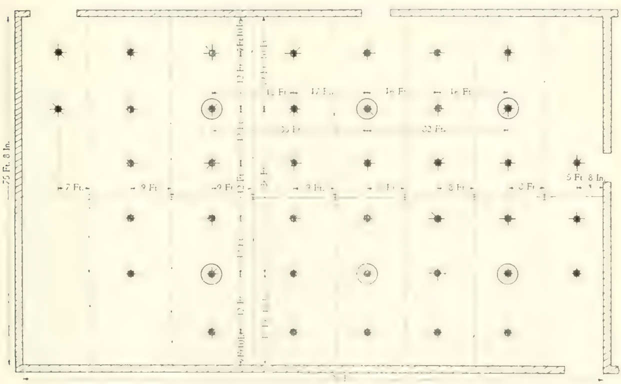


FIG. 8—FLOOR PLAN OF POWER HOUSE SHOWN IN FIG. 7 INDICATING THE COMPARATIVE SPACING OF THE OLD AND THE NEW ARRANGEMENT OF LAMPS IN THE ENGINE ROOM

The circles represent the positions of the old arc lamps, while the stars indicate the tungsten lamps. This is an excellent example of the part played by medium sized lamps as compared with large units of some years ago. The old system consisted of six enclosed arc lamps, while the new consists of 40 250-watt tungsten lamps.

b—Glare reduced by mounting the lamps high and well out of the range of vision.

c—The switching, as indicated in Fig. 7, permits alternate rows of lamps to be turned on for general purposes, while all the lamps may be turned on in a given portion of the room for emergency work.

d—The large number of lamps practically eliminates the tendency towards marked shadows.

e—Incidentally the tungsten lamp possesses the advantage of operation on either direct or alternating-current circuits; requires no auxiliary apparatus; and gives fairly good light over a large voltage range. The large number of lamps with the close spacing admits of one or two lamps being out without destroying the lighting effect, since each portion of the floor space receives light from a considerable number of lamps.

Conduit was used throughout this power plant and waterproof sockets in all locations where dampness existed. Inasmuch

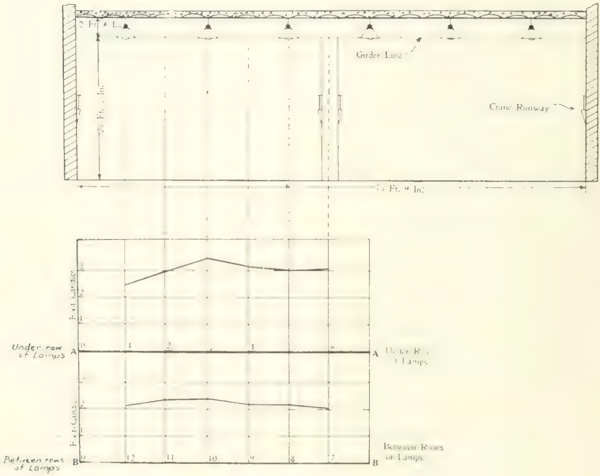


FIG. 9—ELEVATION OF THE ENGINE ROOM SHOWN IN FIGS. 7 AND 8, TOGETHER WITH CURVES SHOWING THE DISTRIBUTION OF THE VERTICALLY DOWNWARD LIGHT ON A HORIZONTAL PLANE THREE FEET ABOVE THE FLOOR

The values plotted on the base lines *AA* and *BB* are from observations taken along the lines *AA* and *BB* shown in Fig. 7. The readings at stations *3* and *10* are slightly high owing to a lamp of slightly higher candle-power directly over station *3*.

as lighting is especially important in case of break-down of the main generating units, it is customary to arrange the wiring so that it can be quickly connected to a steam-driven exciter unit in case of break-down of generators or short-circuit on the switchboard. For the same reason the auxiliary lighting circuits should be entirely independent of the plant switchboard.

The lighting of generating stations and especially sub-stations is doubly important, not only as a means of maintaining service, which would be difficult if not impossible without artificial light, but also because many stations operate for a large part of the time by artificial light entirely. In this particular case the lights are normally fed by a special transformer connected to the station bus-bars, but having no other load. A double-throw switch is provided so that in case of emergency the lighting circuits can be connected directly to one of the steam-driven exciter units. This feature is deemed so important that in some stations the lighting is permanently divided into two separate circuits, one of which is regularly fed from an exciter unit. In sub-stations, where the entire

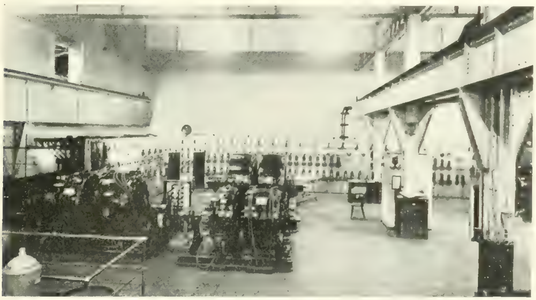


FIG. 10—A VIEW IN THE POWER HOUSE REFERRED TO IN THE THREE PRECEDING DIAGRAMS, IN WHICH 250-WATT TUNGSTEN LAMPS WERE USED

Note the uniformity of the resulting illumination over the floor space. Photograph taken at night.

source of power consists of the incoming lines, it is sometimes deemed advisable to install a small storage battery to provide energy for the station lights, and for the control circuits of power-operated switches, etc., in case of interruption of service on the incoming lines.

NOTES ON THE FINAL ARRANGEMENT

This arrangement of 250-watt tungsten lamps in the engine room and the lighting equipment in the other locations have been in service for a sufficient time to indicate their adaptability to this class of work. At night the engine room presents a bright and cheerful appearance quite in contrast to the dismal aspect of the place

with the original installation. The lamps are mounted on a level with the under side of the girders, as indicated in Fig. 9, and renewals of burned out lamps can be made from the top of the crane without the aid of a ladder.

The bright surroundings of the room contribute much to the effectiveness of the light and it has been found that the shadows are so thoroughly diffused as not to be objectionable. Observations show a resulting intensity of the illumination on a horizontal plane three feet above the floor of about 2.5 foot-candles and the dis-

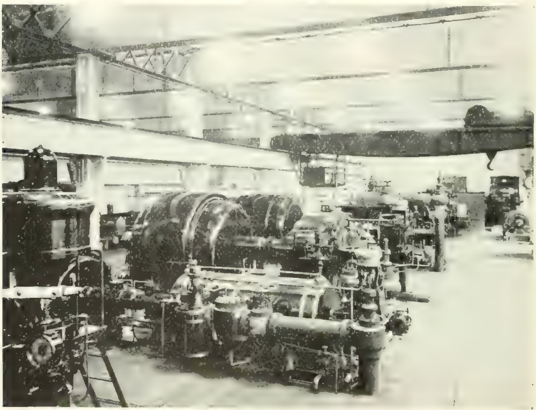


FIG. 11—CLOSER VIEW OF THE POWER HOUSE SHOWN IN FIG. 10 SHOWING THE EFFECT OF LARGE NUMBER OF MEDIUM SIZED LAMPS IN LIGHTING UP THE VARIOUS PARTS OF THE GENERATING EQUIPMENT

Note the uniformity and excellent diffusion of the resulting illumination, as well as freedom from glare. Photograph taken at night.

tribution of the light is indicated by the curves in Fig. 9. These curves are plotted from observations taken at the stations indicated along the dotted lines in Fig. 7.

This example of satisfactory lighting will show the value of medium sized lamps as compared to the larger units. The principles involved in planning this installation, while specifically set forth to apply to this case may be useful in laying out other cases of industrial illumination.

The power house which has been used as an example represents a type of station in which the voltages are comparatively low and transmission distances short, and is typical of many power-stations operated by large industries, in which no complicated switching arrangements are necessary. Practically all stations operating at voltages greater than 2 500 have the bus-bars and oil switches as well as high-tension transformers and lightning arresters in a separate concrete compartment or building, which produce special lighting requirements. Very dim lighting is ordinarily sufficient for these compartments as no one is regularly employed here. Ample lighting should, however, be readily available when necessary in any compartment, as it is extremely dangerous to work in the vicinity of high-tension wiring without adequate light. On account of low ceilings and confined situations, and the fact that the lamps are little used, carbon lamps are ordinarily installed.

In the power house described, and in that illustrated in Fig. 1, the general lighting in the boiler room is such that no special lighting of the water gauges is considered necessary. In laying out the lighting for boiler rooms, this question deserves special attention. Sediment on the inside of the glasses and coal dust on the outside makes the glasses extremely hard to read. The ordinary method of lighting which consists of hanging an incandescent lamp near the glass defeats its object, as the glare of the lamp makes it difficult to see the height of the water. Probably the most generally suitable method is to suspend a white sheet of painted metal or asbestos behind the glass and brightly light this reflector by the general lighting or by a special lamp with a shade which will cut off the direct rays of light from the eye. By this method of lighting the height of the water can readily be noted.

This description has been given to show how a given case was solved. Before attempting to utilize these results for other cases due consideration should be given to the fact that illumination design is dependent on many variables such as voltage regulation, surroundings, whether light or dark, ceiling height, size of bays, architectural details of the building, class of work, and the like. Care should therefore be exercised to ascertain whether conditions exist which call for an entirely different treatment or a modification of the one here described.

THE UTILITY OF PORTABLE INDICATING METERS

ALBERT WALTON

THE ACQUISITION of a set of testing meters by a central station, electric railway or motor-driven mill, affords the possibility not merely of an improvement in conditions but of a revolution. An intelligent analytical engineer with a set of reliable portable meters is the best dividend payer the large user of electrical apparatus can employ. His functions are not dissimilar to those of the auditor in the financial department, the one preventing leaks of dollars and cents and providing efficient methods of carrying on the commercial work, the other preventing wastes of electrical energy and providing means for the most efficient utilization of the power apparatus installed. He is the doctor of the power department, examining, diagnosing and prescribing and keeping the entire system in a state of well being. He has a great advantage over the real physician, however, in that he can ascertain exact internal conditions without guess or peradventure. There is no more exact means of measuring energy than is provided by the modern high-grade electric meters. Until the advent of commercial electric apparatus all power measurements were little better than guess work and any subdivisions or segregations of the total power capacity of a plant or the nature of its distribution were impossible.

It is eminently desirable to know where the energy of the central plant goes, how heavily loaded each machine in the system is and what are the requirements of each department. Without a means of checking up actual conditions the recommendations of a master mechanic or machinery manufacturer must be relied upon and every one who has had to depend on this system has a full appreciation of its shortcomings. Manufacturers of power-driven machines are notoriously faulty in their estimates and are, unfortunately, as liable to errors on one side as on the other. The average master mechanic, with still less data at his command, is even less to be depended upon. The evil results of power installations made without sufficient information upon which to base the selection of motors, transformers, etc., though invisible, are present in many an industry and are generally none the less costly because their existance is unknown to the superintendent or manager. In

many cases investigation will disclose that one motor is loafing along, doing a third of the work of which it is capable, while its neighbor may be staggering under a destructive burden of twice its rated capacity. Many times new machiney has been ordered for a factory and a recommendation made by the mechanical department for motors to drive it, with capacities of, it may be, 20, 50 or 100 horse-power. The manager who has had no experience in meter work may order the motors, whereas the presence of a testing set might enable him to ascertain that there is already the amount of horse-power in unused capacity of motors already installed. By the shifting of machines or motors or a rearrangement of a few belts or countershafts the load might be shifted in such a way as

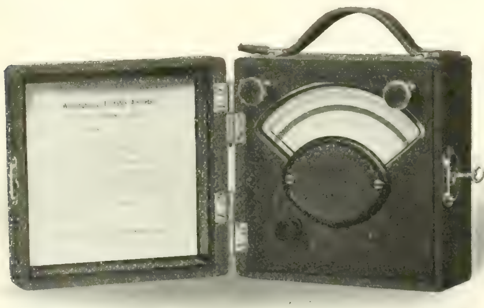


FIG. 1—DIRECT-CURRENT PORTABLE AMMETER

to load up all the motors completely and actually free a motor of the capacity desired. Not only may the cost of the testing set be saved many times over on this one operation but the saving is continuous for the fully loaded motors are running at better efficiency and power-factor than the under-worked machines.

The writer has personally seen a case where a testing set was able to effect a saving all out of proportion to its cost, for it enabled the user to postpone indefinitely the purchase of a new turbine and generator by rearrangement of the loads on a large number of small motors, all of which were so badly underloaded that the generator was carrying a heavy useless load of wattless current. He was thus able to put on additional load, not only with-

out buying a new generating unit but actually with a motor to spare after the rearrangement.

Just what instruments should comprise a testing set for commercial uses cannot be specified without first knowing the character of the work in which they are to be used, whether alternating-current or direct-current, high or low voltage, railway, lighting or mill work, small units or large units, and whether the alternating current is subject to wide frequency changes. In general, however, certain requirements of any testing set can be listed as eminently desirable. Of course, accuracy comes high up on the list of virtues that should be incorporated in all meters, for there is little use in testing unless the results can be relied upon. Present designs of portable meters, however, have reached such a high state of perfection that in some makes of meters the accuracy of measurement is higher than any possible accuracy of reading the position of the needle on the scale, unless it is absolutely still and fixed. The readings are unaffected by ordinary variations of temperature, wave form or frequency. One one-thousandth of full scale reading is a refinement undreamed of in laboratory instruments not so many years ago, yet the central station tester who screws a lamp into the socket on a modern lamp testing wattmeter is sure of his results to that degree if indeed he, himself, is as accurate in his readings. At the same time he might be reading the voltage or the current with equal accuracy.

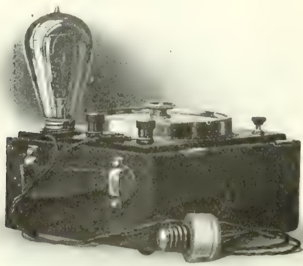


FIG. 2—DIRECT OR ALTERNATING-CURRENT LAMP TESTING VOLTMETER-WATTMETER, OPERATING ON THE KELVIN BALANCE PRINCIPLE

However, the high accuracy of a meter as it leaves the factory is not the chief consideration in a portable testing set, for above all things this accuracy must be permanent. This involves staunch construction of both meter elements and case as well as the method of suspending the meter parts in the case. The permanency is also

dependent, of course, upon the constancy of friction in the moving parts and more especially on the ratio of friction to meter-torque.

With the Kelvin balance principle, used on instruments of the zero reading type, or with the induction principle as exemplified by the direct reading alternating-current meters, permanency is simply a matter of correct design and rugged construction, while a long scale, covering over 300 degrees may be used. With the permanent magnet type of direct reading direct-current meters, continued accuracy is dependent on permanency of the magnets. The highest degree of permanency, if the material has been carefully chosen and properly magnetized, must rest with the magnetic circuit which is disturbed least after being magnetized and in which the air-gap is the shortest. The first requirement can be met

FIG 3—INDUCTION TYPE POLYPHASE WATTMETER

by a design of such a nature that the magnetic system does not need to be disturbed after magnetization, for either assembly or repairs. The second is met most completely by the single air-gap construction, of the type shown in Fig. 4, the invention of which in this form was little short of a stroke of genius. Thus, though built on the D'Arsonval principle, the permanent magnet meters of modern design may be considered as no less permanent in calibration than the other types. And this is true whether the testing engineer is using his meters a dozen times daily or takes them from the cabinet annually for a sort of yearly power inventory.

After carrying a wattmeter, ammeter, and voltmeter a few long, hot, city blocks, a testing engineer is prepared to say that

neither accuracy nor permanency can compare in importance with lightness. With full appreciation of this fact a meter should be chosen which is really portable in the full sense of the term. A great improvement has certainly been made over the olden days, when to carry an alternating-current ammeter from the power house to the sub-station was one good man's job and testing engineers were selected like butchers or football players for brawn and endurance.

Another characteristic which deserves especial consideration is freedom from unnecessary vibration of the needle. Those who have used or seen others use the old types of meters remember observing with a lively interest the nervous spasms of an almost invisible pointer exhibiting every symptom of St. Vitus' dance, as it vigorously cavorted from end to end of the compressed scale, successfully eluding any attempt to read or locate its position on the scale. In contrast with this, the writer has used a modern wattmeter on an individual motor driving a loom whose shuttle made 160 trips per minute and was able to plot a curve of the power cycle and to note that the shuttle was "picked" harder at one end of the loom than at the other, so closely does the needle follow the load. In other words, the perfect meter should be "dead beat." But perhaps the most aggravating defect a meter can have is the compressed scale, for it seems to be fate that the readings of most importance come on that part of the scale that is simply "suggested" and the thickness of a line is a difference of fifty percent of the measured quantity. Contrasted with this is the 300 degree

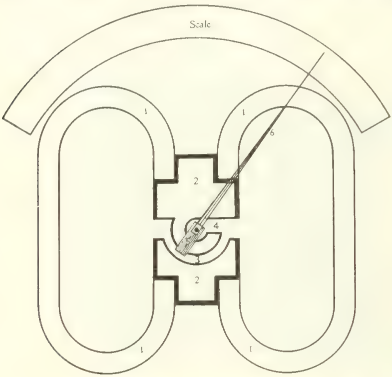


FIG. 4—DIAGRAM OF MAGNETIC CIRCUIT OF DIRECT-CURRENT VOLTMETER OR AMMETER

1—Permanent magnets; 2—Soft iron pole pieces; 3—Air-gap; 4—Slot in pole piece for removal of moving element; 5—Moving element; 6—Pointer, balanced by weight of moving element.

scale of the induction type meters and the long double or triple scales of the permanent magnet instruments in which there are no "favorable parts of the scale," or rather no unfavorable parts since good readings may be taken anywhere from end to end. Not only is this an advantage when the quantity to be measured is more or less an unknown value and liable to fall on any part of the scale but it makes each meter usable over a wide range. The meter that will accurately record the power taken by a 10 horse-power motor will give no less accurately a determination for a one-twentieth horse-power motor driving a family sewing machine. The 750 volt meter that measures the trolley voltage has a three volt scale for measuring the drop in the rail bonds.

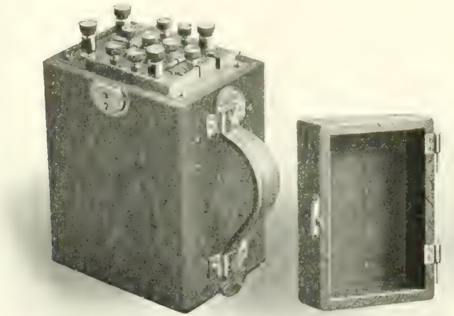


FIG. 5—PORTABLE CURRENT TRANSFORMER

These are a few of the features that have made the modern meter a practical everyday article of the greatest utility and value in any plant where electricity is generated or utilized. Good meters have been made for many years. Excellent meters are the product of the last five years and it is not surprising that the great improvement is only just being appreciated by the electrical men of the country. The manufacture of these instruments has been made a positive art and the finish and workmanship of their moving parts and their coils and windings, their springs, jewels and adjustments are worthy of comparison with the products from the hands of fine watchmakers and silversmiths.

A SWISS 5000 VOLT, SINGLE-PHASE ROAD

ILLUSTRATIVE OF CERTAIN FOREIGN CONSTRUCTION DETAILS

S. Q. HAYES

SWITZERLAND places a great deal of reliance on electric traction for serving parts of the country remote from the through routes of the steam roads, and these electric roads have performed their functions so well that before many years have elapsed it is probable that the trunk lines will also be electrified. The high cost of coal and comparative abundance of water power makes this question of electrification a vital one.

In Switzerland may be found examples of direct-current, three-phase and single-phase railways of both standard and narrow gauge. The combination of single-phase traction and narrow gauge is one that does not exist in the United States. One of the most interesting of these narrow gauge single-phase roads is that equipped by the Ateliers de Construction Oerlikon in the Fall of 1907 for uniting Locarno on Lake Maggiore with Pontebrolla and Bignasco in the Valle Maggia of Switzerland. This valley through the Lepontine Alps parallels the St. Gothard route and runs approximately north and south. As the highway through this valley has heavy grades and sharp bends a private right of way was secured for the railroad, a practically uniform grade being obtained for the entire line, the length of which is 17 miles. The line passes through four tunnels, whose total length is 955 feet. About two-thirds of the line is on tangents and one-third in curves. There are 26 crossings at grade and a total of 25 bridges over rivers and streams. At each of the twelve stations turn-outs are provided so that trains may pass. The rails are laid on one-metre gauge, and weigh 45 lbs. per yard. Although the private right of way involved a relatively high cost of installation it served to shorten the route and reduce the operating cost. Many difficulties were encountered in the construction of the line along the side of the mountain and it was necessary to make many cuts and fills as well as to erect dams and retaining walls to protect the road bed from floods on the Maggia and its tributaries.

CAR EQUIPMENT

A typical train and a repair car are shown in Fig. 1 near the Pontebrolla station. The motor cars are provided with two trucks

and are equipped with hand brakes as well as air brakes. Each truck has eight brake shoes. Owing to the slight grades it was not considered necessary to install electric brakes. The operating voltage is 5 000, except in Locarno, where 800 volts is used. Each motor car is provided with two oil insulated transformers of 90 k.v.a. capacity mounted in the middle of the car. The high-tension windings of these transformers are divided into nine sections connected in series. The low-tension windings are provided with eight taps, as shown in Fig. 2, which allow for steps of about 28 volts from 200 to 400 volts. In Locarno, when operating on 800 volts, the current is taken directly to the secondary of the transformer which acts as an auto-transformer. Eight operative steps, corresponding to these low-tension taps are thus obtained for forward or backward running. A separate cylindrical switch in the controller is provided for reversing.

FIG. 1—TYPICAL TRAIN AND REPAIR CAR NEAR PONTEBROLLA STATION

Showing one of the forms of overhead construction used where there are several adjacent tracks and a cross-over.

Each truck has two 40 horse-power, single-phase series motors of the type shown in Fig. 3. These motors are provided with 13:67 gear ratio and are capable of operating a train weighing 12 100 pounds at a speed of 11 miles an hour on a 3 1/3 percent grade, or with a speed of 18½ miles an hour on the level. The stator of these motors is provided with a compensating winding in addition

to the field winding. The rotor carries a winding interlaced at every six poles with compensating wires and connected to the commutator by low resistance leads. The stator also has auxiliary poles with a commutating winding. These motors are tested for 1 500 volts.

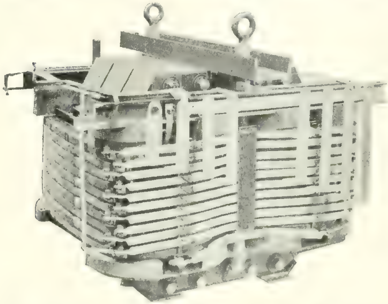


FIG. 2—CAR TRANSFORMER; CAPACITY 90 K.V.A.
Showing the eight low-tension taps corresponding to the operating steps of the controller.

Each car is equipped with two compressors, directly driven through gears by the motors on one truck, which feed in parallel into an auxiliary reservoir and thence into the main reservoir, where a pressure of four atmospheres is maintained. The operating platforms of the cars contain the controllers, brake valves and valves for circuit breakers; an ammeter, a voltmeter and an illuminating lamp; switches for lighting and heating; a hand-wheel to operate the trolley, and a speed indicator.

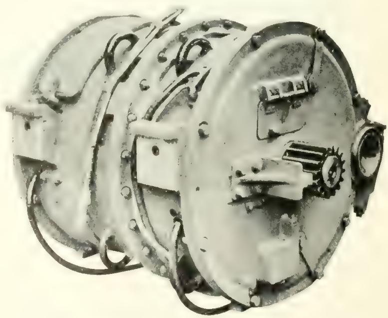


FIG. 3—SINGLE-PHASE SERIES MOTOR
Each car is equipped with two 40 hp motors. Nose and axle suspension is employed.

The high-tension room, which is completely enclosed, contains the apparatus for both the 800 volt city service and the 5 000 volt interurban service. From the high-tension oil circuit breakers the current passes to automatic circuit breakers, which can be operated by hand or by a pneumatic device from the platforms. The automatic overload tripping is done by a solenoid fed from a series transformer. One set of apparatus is provided for 5 000 volts and one for 800 and the breakers are so interlocked that they cannot

both be closed at the same time. The pneumatic operation of the breakers is accomplished by a valve having positions corresponding to the closing and tripping of the apparatus. From the breakers the current passes through the primary windings of the two transformers in parallel and thence to the ground. These transformers are provided with special 55-volt taps for lighting, eight-volt taps for the tachometer, and 200 volt taps for the heating system. For the various lighting requirements there are two reflector lamps, a signal lamp with colored glass on each dashboard, a lamp for each platform and six lamps in the car. The heating is done by means of 14 heaters, each taking 400 watts.

The cars are equipped with three trolleys. Two of these are of the horn type shown in Fig. 4, placed at each end of the car, and connected in parallel for the 5 000 volt service. The third is a bow trolley, located midway between the other two, which is arranged to be fastened down except when in use on the 800 volt city service. The horn trolley is made of steel tubing with a renewable brass cover. A spiral spring serves to press it firmly against the trolley wire with a uniform pressure of approximately 6.5 lbs. for all positions of the horn. Each horn can be operated independently by means of a hand-wheel located on the platform below it or the two can be mechanically connected and operated from either platform. A pneumatic interlock prevents the raising of the horn trolleys if the high-tension compartment is open and conversely prevents opening the high-tension chamber if the trolley is up. The bow trolley is made with two contact bars and is operated from the baggage compartment by means of a rope. This trolley is also interlocked with the high-tension room.

FIG. 4—HORN TYPE TROLLEY

Uniform contact pressure is furnished by a spiral spring. The trolley is lowered by means of a cable and hand-wheel on the car platform.

LINE CONSTRUCTION AND OPERATION

For the ordinary construction of the trolley line the wire is located at the left of the track so that contact is made on the side of the wire along tangents and either on the side or the top of the wire

on curves. At stations and in tunnels contact is made on the under side of the wire. The various details of construction for these respective cases are shown in Fig. 5. For the side contact construction the wire is attached to brackets placed 20 to 40 inches to one side of the track, while at stations and in tunnels the suspension is by means of span wires and messenger cables, the wire being located approximately over the middle of the track. Trolley wire of 100 000 circ. mils section is used. When side mounted the wire is located at a height of 13.5 to 15.5 feet above the rail. At grade crossings the height is 17.5 feet; at stations, 15 to 17.5 feet, and in

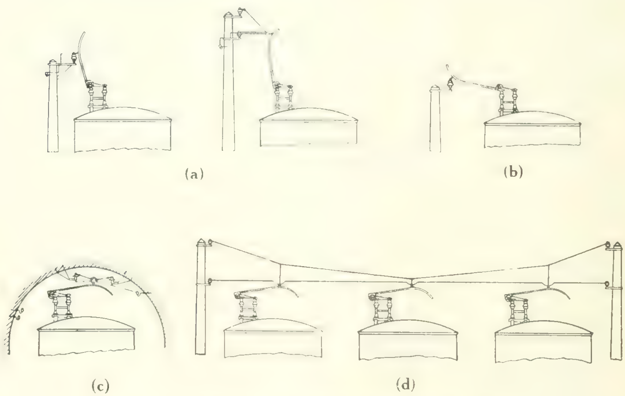


FIG. 5—METHODS OF SUPPORTING TROLLEY WIRE

a—Bracket support for side contact of the horn trolley, as used on tangents and sometimes on curves. *b*—Bracket support for top contact, as used on curves. *c*—Tunnel construction. *d*—Construction used over two or more adjacent tracks.

tunnels, 14 feet. Where there are several adjacent tracks, as at stations, a special form of construction is employed, as shown in Figs. 1 and 5*d*. The arrangement of the overhead construction at cross-overs is also shown in Fig. 1. By means of the sagging messenger wire and the vertical connections, the horizontal span wire is relieved of strains due to the weight of the trolley wire and attachments. At the poles the messenger and span wires are attached to insulators mounted on brackets. These insulators are all subjected to a 30 000 volt insulation test. The distance between suspensions is ordinarily 98 feet on tangents, this distance of course

being decreased on curves and at grade crossings, while in the tunnels the span is about 39 feet.

The line is sectionalized at six points through horn type switches which may be operated either by means of remote control circuits or by hand, and each section of the line is provided with lightning arresters. The remote control circuits are carried on low-tension insulators mounted on the poles about 15 feet from the ground. All of the supports of the high-tension insulators are connected to this circuit through a special form of indicating fuse device. The break-down of an insulator thus results in operation of the sectionalizing switches which disconnect the section in case of trouble. A leakage current from an insulator to the control circuit of even a few amperes will operate the sectionalizing switches, and blow the fuse. The indicating fuse is made of an insulating tube inside which a small copper wire is hermetically sealed, the wire terminating in a metallic cap at each end. One cap of the fuse is attached to the insulator support or bracket while the other goes to the auxiliary wire. The location of a defective insulator is indicated by blowing of the fuse, as one cap is left attached to the support while the other hangs suspended from the auxiliary wire.

A break in the contact wire will also automatically disconnect a section. The high-tension insulators are mounted on pins placed in sockets in which they can turn. Thus, in case a trolley wire breaks, the insulator is turned, and a short auxiliary wire which is fastened to the insulator makes contact with a forked arm attached to the bracket. In this way the control circuit of the sectionalizing switch is energized and the section disconnected.

A telephone circuit is also carried on the trolley poles. It is mounted on porcelain insulators and the wires are transposed at every pole.

GENERATING STATION EQUIPMENT

The generating station at Pontebrolla was originally installed to supply power and lighting to Locarno and contained two 600 hp. three-phase, turbine driven generators. For the operation of the single-phase railway two additional 600 hp. 20 cycle, single-phase, turbine driven units were installed, the wheels of the two sets of units being fed through separate penstocks. The turbines operate at a speed of 500 r.p.m. under a head of 114 to 122 feet, depending on the height of the water.

The regulation is accomplished through movable vanes con-

trolled automatically by a regulator using oil under pressure, and the fluctuating load of the traction service imposes a heavy duty on the regulator. Unless costly appliances were provided to take care of variations in conduit pressure due to load fluctuations it would be impossible to use a regulator which would close the admission valve in less than four seconds. Accordingly, the requirements for good regulation in this station were met by equipping each turbine generator set with a fly-wheel consisting of steel bands weighing about 2 300 lbs. arranged as an elastic coupling between the turbine and generator.

A view of the power house is shown in Fig. 6. A complete generating set, including oil type regulator, elastic fly-wheel coupling and direct-connected exciter, is shown in the foreground. The

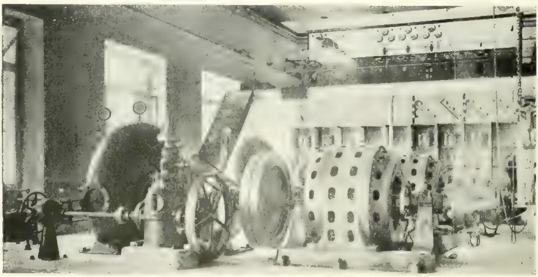


FIG. 6—INTERIOR OF POWER HOUSE

Showing in the foreground, a turbine, fly-wheel and genertor set with direct-connected exciter. The high-tension control equipment is installed in a concrete structure at the rear, while the switchboard is located in the gallery above.

switchboard, which is located in the gallery at the end of the station, overlooking the generator room, is provided with a control desk equipment and instrument panels on which are mounted the various meters, relays, rheostat hand-wheels, and control levers for the high-tension circuit breakers, there being no high-tension apparatus on the switchboard. The circuit breakers are mounted in fire proof cells under the gallery. The current and voltage transformers for the meters and relays are also contained in fire-proof cells. The bus-bars are mounted above the circuit breakers under the operating gallery. A Thury regulator automatically takes care of voltage fluctuations with change of load. Horn lightning arresters with liquid resistances, for protection of the outgoing lines, are located on the operating gallery back of the switchboard.

THE EFFECT OF BENDS AND LOOPS
ON THE INDUCTANCE OF A CONDUCTOR

R. P. JACKSON

IT IS frequently stated that the leads to and from certain apparatus, a lightning arrester, for example, should be as straight as possible and avoid unnecessary bends. This has sometimes been interpreted to require the elimination of short corners, angles, etc., on their own account, as being intrinsically of greater inductance than straight conductor. Strictly speaking this is not true and the only reason for avoiding corners and bends is the simple and fundamental one that a crooked line cannot be the shortest one between two points. In fact, no matter how crooked and intricate the path afforded by a conductor, so long as one loop does not lie over another, its impedance cannot be greater and is, in fact, somewhat less than the same conductor stretched out straight. It is true, however, that such a tortuous path has greater impedence than one following an approximately straight line between the terminal points. This statement may not appeal to one who has been in the habit of looking upon loops and bends in a conductor as having an inductance which is at least greater than the same length of straight conductor, but a simple demonstration may make this more clear.

The inductance of a single turn of wire in the form of a circle is double that of a second similar loop of half the diameter. Consequently for similar loops the inductance is proportional to the length of the wire or, in other words, the inductance is the same per foot of wire. If the loop be made very large, then a small section of it, say a few feet in length, is approximately a straight line and its inductance may be considered as equal to that of a straight wire. Hence, the inductance of a foot of wire carrying a given current is the same whether this wire forms a part of a small loop, or a large one, or a straight conductor.*

Assume, for example, loops A and B of Figs. 1 and 2, loop B, having twice the linear dimensions of A, and of course an area four times as great. Suppose the area of A be divided into, say, 1 000 little portions dA and the circumference into a similar number of short arcs da. We can divide B up into the same number of por-

*These statements are not quite correct as the diameter of the wire has an effect which has not been considered. Furthermore, the statements do not apply to coils in which there are two or more turns. To be strictly true, the diameter of the conductor must vary also with the size of the loup. If not the inductance increase slightly more rapidly than the linear dimensions of the loop.

tions and dB will, of course, have four times the area of dA, and db will be twice as long as da. Now db being twice as long as da the magnetic effect at any point of a current flowing through it will be twice as great. Small elements also like dA and dB will be magnetically affected by da and db inversely as the square of their distances from the same. In general, since the linear dimensions of B are twice those of A, distance R will be twice distance r and the magnetic effect of a given current in db on dB will be one-half that of a similar current in da on dA, i. e., $\frac{1}{4} \times 2 = \frac{1}{2}$. However, the area of dB being four times that of dA and its flux density one-half as great, it will contain twice the flux. There being the same number of elements dA and da as there are dB and db, the same condition holds for the whole circles or loops of whatever shape

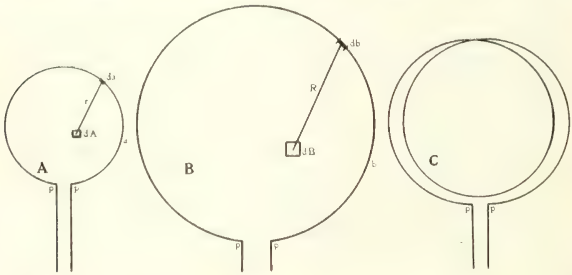


FIG. 1 FIG. 2 FIG. 3

so long as they are similar. In other words the flux for a given current, or the inductance, varies directly with the linear dimensions of similar loops and coils, and the inductance is the same per unit length of conductor.

Now suppose that loop B were many times as large as A and that a length of such conductor equal to loop A from p to p would be practically a straight line. Its inductance would be the same as loop A. (Practically a little greater if the wire were the same size). Thus loop A from p to p has no greater inductance than the same conductor stretched out in a straight line. In other words, bends, loops and corners are harmful only because they involve more conductor and not because such loops and bends in themselves increase the inductance. This is not the case, however, if one loop overlaps another as in Fig. 3. In this case the inductance increases in general as the square of the number of turns.

Sharp points are bad whether at bends of the conductor or elsewhere but for reasons due to the static rather than the magnetic field.

The production of magnetic lines around a conductor or through a coil by magneto-motive force is quite analogous to the flow of current through a resistance as the result of an e. m. f. In one case the flow of energy is proportional to the value EI and in the other case the stored energy is proportional to the value HB, where H is the magneto-motive force and B the flux density. With a given loop or coil if H be doubled by doubling the amperes, B will also double and their product or the stored energy will be four times as great. The same is true if the e. m. f. applied to a fixed resistance be doubled—the energy input is quadrupled.

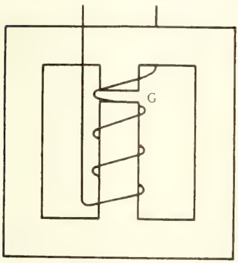


FIG. 4

If a coil of given shape has the number of turns doubled the value of H for the same current is doubled and the magnetic reluctance remains the same, so B is doubled and HB or the stored energy is quadrupled. In this case, also, as the stored energy per unit current is quadrupled, the value of L or the coefficient of self-induction, which is a measure of this value, is correspondingly quadrupled.

This fact that the stored energy is proportional to HB develops another fact which is sometimes unsuspected. Take a coil such as shown in Fig. 4 with an iron flux path. If there is no air-gap the flux per unit current is greatest but the stored energy for a given flux is not. If an air-gap G is introduced the value of H must be largely increased on account of the reluctance of the air-gap. The stored energy HB then becomes correspondingly greater. If the coil is in a series relation to the circuit, it is most effective if the air-gap G is just large enough to permit saturation of the iron of the circuit.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburg, Pa.

608—Specifications for Silver Chloride Test Cells—Please give directions for making up silver chloride cells, such as are in general use in testing outfits, especially regarding the preparation of the electrolyte and the material used for hermetically sealing the glass cells. H. M. S.

So far as we can determine, silver chloride cells are no longer used. They were in use 15 or 20 years ago, but did not prove satisfactory. We have no details as to their manufacture. Any of the present forms of standard cells, the Clark, Carhart-Clark or the Weston would probably fulfill your requirements. The Clark cell has been the legalized standard in the United States. Its e.m.f. is 1.434 to 1.433 volts at 15 degrees C. The electrodes consist of zinc amalgum covered with a layer of zinc sulphate crystals and metallic mercury; the electrolyte being a saturated aqueous solution of zinc sulphate and mercurous sulphate. The Weston cell is at present the adopted form of standard cell in the United States. It promises shortly to be accepted as the international standard. The electrodes of the Weston cell consist of cadmium sulphate crystals, and pure mercury in contact with a paste of mercurous sulphate, cadmium sulphate crystals and metallic mercury; the electrolyte being a concentrated aqueous solution of cadmium sulphate and mercurous sulphate. The e.m.f. of the Weston cell is 1.0186 volts between 5 and 26 degrees C. With the exception of its lower e.m.f. it has many advantages over the Clark cell, among which the most important is its low temperature coefficient, which is about 20 times smaller than that of the Clark cell. It also has a longer life, and many other advantages which are sure to place it before the Clark cell. For sealing such a cell, wax, paraffine or some electrical insulating and impregnating compound may be used. C. E. S.

609—Locating Trouble in Telephone Cable—Several short-circuits have developed in a cable installed in connection with a central energy telephone system located in a large industrial works. When a call button is pressed more than one phone rings; cross talk also interferes with the service. As a result of the trouble the batteries deteriorate rapidly. Five hundred to six hundred feet of the cable is supported on 30 foot poles, and it is probable that the trouble is in this section and traceable to dampness. How may the cable circuits be tested to locate the short-circuits without removing the cable from the poles? E. W. B.

The following method is suggested: Remove the attachments from several of the cable pairs and test the pairs for ground by passing a current from a battery giving 25 to 50 volts through a voltmeter in series with the conductor, one side of the battery being grounded. If the cable pairs are clear you will get no deflection on the voltmeter. If you do get a deflection on the voltmeter it indicates low insulation resistance and the trouble should be cleared. The trouble can be located by either the Varley or Murray loop methods. These tests are very common and are published in the various engineering handbooks and many text books. An ordinary bridge may be used for locating the trouble, but it is better to use a special trouble locating set, such, for example, as are made up by Queen & Company or Leeds-Northrup Company. After the trou-

ble is located the cable should be opened at the point where the location shows and the trouble cleared by boiling out the insulation with hot paraffine and closing up the cable again by means of a lead sleeve and wiped joint. R. A. L. S.

610—Exciter Conditions with Tirrill Regulator—We have three 70 kw, 2 300 volt, three-phase, 60 cycle, 277 r.p.m. alternators, to each of which is belted one 125 volt, seven and one-half kw, 1 200 r.p.m. compound-wound exciter. We have recently installed a Tirrill voltage regulator, necessitating a bus-bar for our exciters, whose speed was increased from 1 200 to 1 340 before the installation of the Tirrill regulator in order to get increased exciter capacity. Upon the installation of the regulator, the series windings of our exciters were shunted, reducing the over-compounding from 40 to five volts, at full exciter load—60 amperes. The alternators are of the revolving field type, designed for unity power-factor. *a*—How much more exciter current at 125 volts is required by these alternators at full-load (kva) and 60 percent power-factor than unity power-factor? *b*—How much has the installation of the Tirrill decreased our exciter capacity (we are now unable to generate more than full-load with the regulator short-circuiting the exciter)? *c*—How can we continue operation of the regulator and generate 140 percent full k.v.a. load as previously, without fall in alternating-current voltage? *d*—What type of exciter winding would you recommend for a new plant with Tirrill regulation? *e*—With Tirrill regulation, are we increasing the liability of our exciters to sparking by commutating current at 40 to 160 volts (average 125, voltmeter reading) under normal conditions? (49-bar commutator—Tirrill operating 180 times per minute.) *f*—Would inter-poles give better commutation with Tirrill regulation because of question *e?* J. M. W.

Whereas the question states that the over-compounding of the exciters had been reduced from 40 to five volts, it is hardly possible that the exciters were over-compounded to that extent; what was probably meant was that the characteristics of the exciters are such that they require about 40 percent of the total ampere-turns in the series fields to give a constant voltage at the brushes, and probably more of the compounding was cut out than necessary. The compound winding should be shunted sufficiently to give a drop in voltage of about 12 volts. To do this, proceed as follows: At no load and constant speed of 1 340 r.p.m. adjust the exciter voltage to 112, always with falling voltage and no load, then put on full load and the voltage should fall to 100. These tests or adjustments should be made with a water rheostat load. With the adjustments made as above the trouble will probably cease. In reply to the numbered questions: *a*—Very much; the actual amount should be obtained from the manufacturer or by tests. *b*—Not any; adjust the compound winding as above and put ammeters between exciters and bus-bars and the results will be satisfactory. *c*—By adjusting the compound winding as above and following answer to *b*. *d*—For good practical design and operation, would recommend an exciter having low armature reaction so that not more than 25 percent of the total field ampere-turns would be required in the series winding to give a flat voltage of 125 on exciters designed for such voltages; the shunt field current should be low, and the exciter should give at least 160 volts at full load. *e*—No, the sparking will be less because the Tirrill maintains at all times the lowest possible exciter voltage to give the required alternating-current voltage. *f*—Yes, but the same precaution must be taken in the design of such exciters, as the inter-poles act the same as the compound winding and should not have an effect of over 25 percent of the total field excitation; see answer to *d*. A. A. T.

611—Operation of Interpole Machines—In the testing department of a certain factory it is the practice to obtain rated speeds on motors by shifting the brushes from the neutral. The motors are interpole, and considerable variation may be obtained before sparking occurs. Is this good electrical engineering? Is it admissable to put a shunt on an interpole machine of say 150 kw, or could it be considered as a reflection on the design if a machine of this size required a shunt on the interpoles to secure good commutation. W. F.

As a rule it is not good practice to shift the brushes from the neutral on interpole machines. Good commutation may be secured with shifted brushes provided the interpole strength is properly adjusted, but the speed of the motor will not be the same for both directions of rotation, the commutation will not be as good in one direction as in the other, and the stability of the motor may be affected. Since the polarity of the interpole in a motor is the same as the polarity of the preceding main pole, a backward lead of the brushes causes the interpole flux to demagnetize the main field, so that with increase in load, the main field is weakened, which may make the motor unstable. It would not be objectionable on a generator of the size mentioned to shunt a small proportion of the total current out of the interpole winding. While it is possible to calculate the strength of the interpole winding sufficiently accurately for an average condition so that a shunt would not be necessary, it is usually desirable in designing machines of this size, to make them adaptable for a wide range of operating conditions. It is, therefore, often desirable to have some excess ampere-turns on the interpole winding so that the strength of the interpole field may be adjusted, if found desirable, to meet severe or unusual operating conditions. G. B.

612—Paralleling of Two Systems—We have under consideration the tying in of two high-tension, 60 cycle, three-phase transmission systems, each of such extent that change of operating voltage of either system as a whole, cannot be made. There are both water power and steam generating stations, supplying power as far as 100 miles. The voltage of one is 66 000 and of the other 60 000 volts. The connecting point will be approximately fifty miles from the nearest sub-station. Please suggest suitable apparatus for tying these two systems together, in order that power may be taken in either direction up to capacities of about 1 500 kw. R. U. F.

There is no reason why two such systems cannot be tied together by transformers. Further, with a difference of only 10 percent in the voltages, as indicated, there is no reason why auto-transformers cannot be used for tying the two systems together. The adoption of auto-transformers, however, will mean that any ground on one system will also become a ground on the other—a condition which would be avoided by the use of two-coil transformers. However, the cost of the necessary auto-transformers would be only about 10 to 20 percent of that of the two-coil transformers, hence making the auto-transformers much preferable insofar as cost is concerned. See "Paralleling Large Alternating-Current Systems" in The Journal for May, 1910, p. 386. P. M. L.

613—Loads of Leading and Lagging Power-Factor Paralleled on Generating Station—In the operation of a three-phase, 25 cycle, 6 600 volt system, the generating station is located midway between two loads. The load on the feeders in one direction consists of induction motors, with an average power-factor of 85 percent lag, and the load on the feeders in the other direction consists of synchronous motors. The generating station power-factor is maintained at unity by making the power-factor of the synchronous motors lead enough to overcome the lag of the induction motors. Would such a

scheme be considered as an economical condition of operation?
F. M.

Unity power-factor at the generating station is obtained by over-exciting the synchronous motors mentioned in this question so that they take a *leading* wattless current to exactly the same extent that the induction motors take a *lagging* wattless current. There is therefore an exchange of wattless current between the synchronous motors at one end of the transmission line and the induction motors at the other end. No part of the wattless current circulates through the generators. It does not matter much whether the wattless current that necessarily is taken by the induction motors is circulated through the generators or the synchronous motors. As a matter of fact, with the arrangement of circuits as indicated in the question, there would be somewhat greater line loss due to circulating the wattless element through the synchronous motors than through the generators since the wattless element in the latter case would only have to go as far as the power plant and would not have to be transmitted through that part of the transmission line between the generators and the synchronous motors. A very slight reduction in line loss might therefore be obtained by taking the wattless element through the generators rather than through the synchronous motors. However, this is probably a very insignificant amount of power. If the synchronous motors and the induction motors are located at the same end of the line, then the transmission conditions could be bettered by compensating the wattless element of the induction motors by the synchronous motors instead of allowing it to pass through the generators and intervening line. It is the arrangement of the transmission line that makes this course not so advisable in the case mentioned above. P. M. L.

614—Storage Battery on Ten-Ton Auto-Truck—What average life may be expected for the positive plates of storage batteries? Of the negative plates? The battery cells in question are Westinghouse 9-R-3 and Electric Storage Battery Co., Type ELS-9 Tudor Accumulator. These batteries are operating ten-ton auto trucks working ten hours per day and pulling three loaded trailers around curves and over crossings, switches and frogs which are in bad shape. The trucks have 48 cells each. When they are put on charge at night, i. e., from 6 P.M. to 7 A.M., the meter shows from 40 to 50 amperes. The trucks are also charged one-half hour at noon each day. Would the later type of Edison battery be suitable for these trucks? H. E. J.

With careful attention, and worked as these are, the positive plates will give a life of two years, and the negative plates a life of from five to ten years. The new Edison type of cell would probably be suitable for this service. Edison plates are doing well in auto service, but their life has not been definitely determined. Their cost and capacity are higher and their efficiency lower than the above standard types of battery. N. R.

615—Rotary Gas Engine—Is the principle of internal combustion applicable to the rotary engine and if not, what difficulties, mechanical or theoretical, stand in the way of developing an engine of this sort? Will you please also tell me of any appreciable progress in the development of gas turbines, and if there is as yet any literature on this subject. G. A. B.

A rotary gas engine can be made and will run satisfactorily, but it should not be expected to give a high efficiency on account of the greater cooling surface exposed in every form of rotary engine known. Gas turbines have been made which run well, but so far they have not shown high enough efficiency to justify their use. The principal difficulty is to obtain the necessary compression. It is sufficient for one to read up on the design of low pressure turbines such as those used with reciprocating engines, to appre-

ciate that the turbine is not as efficient at the higher pressures as the engine, and the higher pressures must be used to get good economy. A good book on this subject is that entitled "The Gas Turbine," by H. H. Supplee. A. T. K.

616—Phase Relations Between Primary and Secondary of Three-Phase Star-Connected Transformers—In a bank of transformers with primary and secondary star-connected would it make any difference which coil terminal was connected to the neutral? Would the transformers work equally well in each case? W. L. M.

If three single-phase transformers are connected star to star on a three-phase circuit, it does not matter which coil terminal of either the high-tension or low-tension side of each transformer is connected to the neutral so long as the connections are made in such a manner as to give the proper phase relations. The connections of one side can be made using whatever terminals are desired for the neutral but, when this connections is once made, the phase directions of the voltages of all the windings are fixed and the connections of the other side must be made in such a way as to combine the voltages in their proper phase relations. Figs 616 (a), (b) and (c) show correct connections while Fig. 616 (d) is incorrect. The respective voltage relations of these connections are also shown in Figs. 616 (a), (b), (c) and (d). From these diagrams it is readily seen that two banks of transformers connected as per Figs. 616 (a) and (c), can be operated in parallel, but if they are connected as per Figs. 616 (a) and (b) or (b) and (c) they cannot be operated in parallel. For parallel operation of two or more banks not only must the phase relations be correct but the directions of the voltages with respect to corresponding terminals must be the same. W. M. MCC.

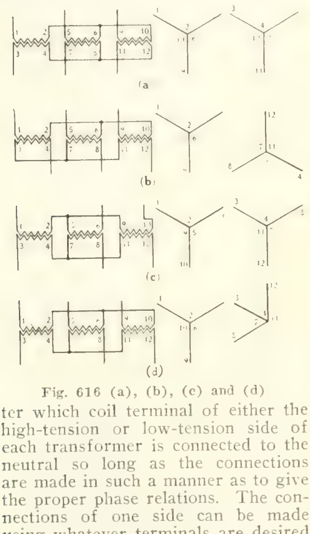


Fig. 616 (a), (b), (c) and (d)

617—Reversal of Wattmeter on Low Power-Factor—I have read that a polyphase wattmeter would run (power-factor below 50 percent) fast on light loads; I made a test on two out of a lot of 25 *new* standard wattmeters lately and found that, at four percent of normal capacities and 20 percent power-factor, both meters registered four percent slow. Was my test an exception in the results attained? F. G. F.

A polyphase or single-phase meter on low power-factor and light load may run either fast or slow, depending entirely on the power-factor adjustment. If the meter be under-compensated, it will run slow, and if over-compensated it will run fast on lagging current. Meters correctly compensated will run correctly with a power-factor quite low, but with a power-factor as low as 20 percent a slight error in the compensation begins to cause a noticeable error in the readings. A. W. C.

CORRECTIONS

In the article on "Securing Factory Loads for Central Stations" in the July issue, page 614, first paragraph, the water evaporated should read "5 610 000 pounds," thus giving a rate of "evaporation of 7 pounds of water per pound of coal."

In the article on "Comparative Capacities of Alternators" in the August issue, page 680, fifth line from bottom, the expression appearing as "$\left(\frac{A^2}{2}\right)$" should read "$\left(\frac{A}{2}\right)^2$"

THE
ELECTRIC JOURNAL

Vol. VIII OCTOBER, 1911 No. 10

Recent Improvements In Railway Apparatus

A brief retrospective survey of the railway field is all that is necessary to convince one that the last word has not yet been said on any line of railway apparatus. New methods and new developments are continually being presented for the consideration of railway operators. Many of the new designs are detail improvements based on practical operating experience and of the kind that tend to eliminate failures; others are fundamental and tend to modify railway practice in general. An outline of some of the more important improvements in railway apparatus which have been made during the past year, as given in the following paragraphs, should prove of interest to railroad men in general.

MOTORS

Notwithstanding the excellence of the interpole railway motors in use a year ago, further improvements have been suggested and developed into commercial form. The use of forced ventilation to increase the capacity of the motors has been tried out on a large scale on the Pennsylvania and Long Island Railroad cars. The motors have a nominal rating of 220 horse-power but the use of forced ventilation enables the motors to be operated at a much higher continuous rating than would be possible without it. The method of applying this ventilation is unique. A small motor-driven blower, or rather pair of blowers on each end of the motor armature shaft, is mounted underneath the truck bolster, and each fan furnishes air to one motor. The air supplied to these blowers is taken from an inlet, well up on the side of the car, so as to avoid the introduction of dust and dirt from the roadbed into the motors.

The use of forced ventilation has been quite common on locomotives, notably on the New York, New Haven & Hartford Railroad, the St. Clair Tunnel, the Spokane & Inland and others, for some years, but this is the first time that forced ventilation has been applied to car motors on any large scale. There is also a tendency toward ventilating small motors by means of fans on the armatures, either with open or closed motors. This is the re-

sult of the demand for light weight motors. The use of motors with incombustible insulation is another result of this light weight motor demand.

FIELD CONTROL

The speed of the passenger locomotives on the New York, New Haven & Hartford Railroad, when operating on direct-current, is controlled by varying the strength of the field of the motors. This method was found to be so eminently successful, after having been in use for about four years, that the same plan was adopted for the Pennsylvania locomotives. These locomotives have only two motors and consequently would not have as wide a range of speed control of the motors as locomotives having four motors, connected in series, series-parallel, and parallel. On the Pennsylvania locomotives, the motors are connected; first, with full field series; second, normal field series; third, full field parallel; fourth, normal field parallel. This control thus gives four highly efficient operating speeds. The full field gives an enormous tractive effort at low speeds with comparatively small current, and the normal field enables the locomotives to haul comparatively heavy loads at high speeds; thus enabling a motor of given capacity to be used over a much wider range of speeds, and with less power consumption than would be possible without the field control. This whole system has been remarkably successful and has never given the slightest amount of trouble. The commutation of the motors is perfect, regardless of the field strength used, and proves conclusively the great flexibility of the modern interpole railway motor and its adaptability to conditions of operation which would not be possible with the old non-interpole form.

The success of field control on these large locomotives has resulted in the application of the same feature to the control of ordinary street car motors, for both slow speed city service and high speed interurban work. The advantage in slow speed city work is that the motors may be wound for a very low speed with full field, which will insure the minimum amount of operation on resistance, and the normal field makes it possible to operate the car at higher speeds when they reach the surburban sections of the line and have less interference. It virtually gives a high speed equipment with an extremely small rheostatic loss in starting, and the saving in power may be very considerable, depending of course on the amount that is ordinarily lost in the resistance. There is a distinct saving in weight as well as in efficiency of operation, as the

decreased resistance loss means less resistance grids to carry around, and in many cases also the motor is lighter. The advantage of field control on interurban work is due to the fact that the cars may be started with much smaller accelerating currents, and are thus better adapted for local service, and yet are able by means of the field control to operate efficiently at a very much higher schedule speed for limited service. Ordinarily, where cars are used interchangeably for local and limited service with direct-current, either one or the other class of service must be somewhat slighted, or the equipments will be badly overworked. The use of field control avoids both of these contingencies. The operation with the normal field enables the motors to haul the cars very much easier in local service, and yet provides all of the speed necessary for a first-class limited service. This system may be used with either the multiple-unit or hand control.

HIGH VOLTAGE DIRECT-CURRENT APPARATUS

The Piedmont Traction Company and the Greenville, Spartanburg & Anderson Railway Company, which form two branches of a new railway system in North and South Carolina, are now being equipped by the Westinghouse Company, with 1 500 volt direct-current apparatus. This is a distinct advance over any other direct-current voltage in this country, and is moreover the largest high voltage direct-current installation ever undertaken. It involves the equipment of about 135 miles of railway, including both car equipments and freight locomotives.

MULTIPLE-UNIT CONTROL

Marked advances have been made in the use of multiple-unit control, both for city cars and interurban work, in the past year. The new simplified unit-switch control has been enthusiastically received on both city and interurban lines, and meets the demand for a simple, effective control which will replace the hand control on the platforms of cars without great addition in either cost or weight. In many cases, in fact, the weight is less with the new multiple-unit control than with the old hand controllers. As the desirability of keeping controllers carrying large currents away from car platforms is becoming more apparent every day, a rapid turning of the sentiment of operating men toward this form of control is to be expected. It not only employs a smaller number of switches than any multiple-unit control heretofore used, but the number of inter-

locks is so much reduced as to enable them to be practically forgotten as far as cost of maintenance is concerned. Line current is used for operating the valve magnets for the switches, and a type of resistance is used in series with these magnets which is of the most efficient form.

SINGLE-PHASE RAILWAY SYSTEM

Steady advance in the use of single-phase apparatus has been made for railway work. In the past year, the Rock Island & Southern Railway, has begun operation with 11 000 volt, single-phase current on the trolley, and the apparatus has operated with the greatest success. The New York, New Haven & Hartford Railway Company has been extending its electrical zone, and has purchased a number of different locomotives with the view of establishing the best type both for its passenger and freight service. The latest type of locomotive is one which is equipped with four driving axles, but has eight motors, there being two motors geared to a quill surrounding each axle. This equipment, which, on the face of it, appears more complicated, is in reality lighter, cheaper and simpler than a locomotive of the same capacity having four motors of the same total capacity. It permits the use of comparatively small motors for locomotives of large capacity, and thus renders motor repairs a much simpler matter. Each of the small motors has practically one-half the number of brushes, brush holders, armature field coils, etc., as one large motor, so that there is the same total number of these parts on the locomotives as with the large motors. There are, therefore, no more chances for failure of the small motors than for the large ones, and the cost of repairing a small motor, as the result of a defect, will be very much less than repairing the same defect in a large motor. The pinions of both motors mesh with one gear on the quill, whereas large motors require twin gears. It is believed that this type of locomotive marks a distinct advance in the art.

The New Haven Company has also a straight alternating-current switching locomotive which, from the time of its arrival at Stamford several months ago, has been on duty at least twenty hours per day. It has been a great success, and is doing the work of two steam locomotives. Fifteen additional 80 ton, switching locomotives of this type are now being built.

The Boston & Maine Railroad Company has in the last few months electrified the Hoosac Tunnel with 11 000 volt, single-phase

current, and has been operating since the latter part of May, handling all of their service with straight single-phase locomotives. Six locomotives are now in use, each having a rating of approximately 1 500 horsepower. Half of these are geared for a minimum speed of approximately 30 miles per hour, for handling heavy freight trains through the tunnel. The others are geared for 50 miles per hour and are used for handling the passenger service. These locomotives weight approximately/130 tons each. This installation is especially notable on account of the difficulties encountered in installing the apparatus, and the faultless operation that is secured with 11 000 volts on the trolley in the tunnel. A contrast between a trip through the tunnel under the old conditions with the tunnel full of smoke and the present delightfully cool air is most marked.

The New York, Westchester & Boston Railway is also being electrified with the single-phase system at 11 000 volts. The equipments are to be interchangeable with those on the New Haven line but are to operate on alternating current only. They will be used for high speed passenger service with multiple-unit cars.

Most of the difficulties on single-phase railways in the earlier installations were due to operation at abnormally high speeds, at speeds for which the equipments were not designed. These speeds were made possible because of the fact that the line voltage was always good, and an over-voltage tap on the transformers was usually supplied. Further, the motors have naturally a very steep speed characteristic, which enables them to reach a much higher speed than would be possible with a direct-current motor with the same gearing. This trouble from overspeeding is now avoided by the use of what is known as an overspeed relay. This relay is electrically operated, and placed in the control circuit in such a way as to be governed in its operation by the current and voltage applied to the motors. It is so arranged that the control circuit will be opened on the higher notches of the controller, if the speed reaches a certain definite limit. It is thus impossible to operate these cars above this limit unless there is a long down grade of over one percent, which is unusual on interurban lines. In any case, if they are operated at excess speeds, they are operated without power on the motors. This scheme might safely be applied to direct-current lines, as well, since extreme high speeds are not only dangerous, but in practically all cases are unnecessary and are also expensive, because of the extra power consumption which is involved.

LINE CONSTRUCTION

There is a notable tendency toward the use of a higher grade of trolley construction; steel poles and bridges are more often seen and steel catenaries with new types of hangers, etc., are more in evidence. The new catenary construction on the Boston & Maine at the Hoosac Tunnel, and in the Harlem River yards of the New Haven Railroad are especially worthy of mention.

SUBSTATIONS

The equipment for direct-current substations is also being improved rapidly. Higher speeds for rotary converters and motor-generators are common and larger overload capacities are given.

In fact, there is no line of apparatus used on railroads which has not shown a distinct advance in the past year.

N. W. Storer

The Problem of Block Signaling

It must not be supposed that the only recognized block signal, or the only good block signal, is automatic. On the contrary, in Great Britain, where not a mile of railroad carrying passengers is permitted to operate without block signals, and where the railroads are operated with much greater safety than in the United States, automatic signals are practically unknown. This is essentially true also on the Continent of Europe. In the United States, at the end of the year 1910, about twenty-nine percent of the steam railroad mileage was protected by block signals, but the mileage protected by automatic block signals was only about seven and one-third percent of the total steam railroad mileage.

It is true, however, that automatic signaling in the United States is increasing much faster than any other kind of block signaling. In the years 1909 and 1910, the increase in miles of non-automatic blocks was thirteen percent, while the increase in miles of automatic blocks was forty-two percent. Automatic blocking began in the United States and has spread here, and it is not used in Great Britain, all in obedience to certain underlying conditions which have affected the whole railroad system and methods in both countries, and which, indeed, have affected all other industrial developments. The most important of these conditions are density of population, rate of interest on money, current wages, and the attitude of the people toward law and discipline.

It must not be assumed that we here introduced and have used automatic signals because we are more intelligent or more ingenious, or more enterprising than other people. All of this opens up an attractive field for speculation into which we cannot enter now.

While the simple telegraphic block, or in a little higher development, the telegraphic block controlled from cabin to cabin by electric locking, may be entirely satisfactory in Great Britain under the social and operating conditions which prevail there, automatic blocking is much the best for American conditions, which fact is now finding expression in the rapid growth here of automatics. These governing conditions apply on cross-country electric roads just as they do on steam roads, only in somewhat less degree, because of slower speed, lighter trains, more frequent stops and less frequent train movement.

The more trains there are to be moved in a unit of time or on a unit of track, the shorter must be the blocks, the extreme being now reached in cases like the Interborough system, in New York, where the minimum length of block is determined only by the safe braking distance. If blocks six miles long will take care of the traffic, it may be permissible, and even desirable, to have an operator at each signal, but if the blocks must be brought down to a quarter of a mile in length to get the requisite number of trains over the road, no further argument is needed to prove that the signals should be automatic, if only to save the wages of operators. Somewhere between these limits will be found the line where it will be cheapest to use automatic signals regardless of other conditions. Beyond this, however, are some important considerations. Automatic signals with continuous track circuits do a number of important things which cannot be done by manual signals. They will usually (not always) detect a broken rail; many accidents have been averted in this way. They will sometimes (not usually) detect a wreck on, say, the east bound track that has spilled over on the westbound. They will detect an open switch in a block. They do not go to sleep, or forget orders, or do a number of other wrong things which human operators sometimes do. On the other hand, they do not, unfortunately, report a careless engineer or motorman who runs by a red signal.

The conditions which call for automatic signaling on steam railroads are precisely reproduced on roads operated by electricity. In heavy electric operations like the modern New York City roads and the great electrified terminals, automatic signals with continuous

track circuits are imperative. In city streets they are impracticable. On cross-country roads is the debatable ground, there the policy of the management must be governed by the complicated conditions of each case, and these conditions are not merely engineering conditions, but they are social, legal, commercial and financial as well.

H. G. Prout

Hazard in Overhead Crossings

An electric light and power circuit creates a fire hazard and often a life hazard also. It may be great or small. Ignorance and carelessness may make the hazard great; intelligence and care may render it very slight. To minimize this hazard should be the first concern of all those responsible for electric circuits, from the standpoint both of good electric service and of obligation to the public.

An advanced stand is being taken by public opinion and by lawmakers regarding the responsibility and the liability of the employer and the public service corporation. Public service commissions are looking after public interests in a new way, employers' liability laws are being enacted, and there is a growing disposition to regard the misdeeds of corporations as resulting from the criminal shortcomings of their individual officers.

Intelligence and care in reducing electrical hazards must be exercised; if not by the companies themselves, then it is certain as fate that it will come through compulsion, possibly by laws that are more drastic than wise.

It is often difficult to determine what is best—and to secure its adoption—in the simpler and easier cases. In house wiring, the wood fittings and the Underwriters' wire of early days are things of the past, thanks largely to the progressive attitude of the Underwriters and the exacting requirements of their wiring rules. The problem presented by high voltage circuits is different and is sometimes peculiarly difficult. Low voltage circuits have had the advantage of better materials and improved methods of construction for meeting substantially the same conditions, while high voltage circuits have been increasing in pressure and in the power carried.

It is simple to install and protect a circuit *per se,* compared with the protection of a low voltage circuit when it comes in contact with a high voltage circuit. It is, practically speaking, impossible to eliminate a great fire and life hazard when a lighting circuit or a telegraph or telephone line is in contact with a high voltage

transmission circuit. The wiring in houses and offices is not insulated to withstand voltages which can jump across an air space of an inch or more, end even if they were, the life hazard might be still greater.

The way to reduce the hazard is to reduce the chance of contact between the circuits by keeping them apart, widely separating them when practicable, and employing the best mechanical construction where the crossing of the circuits or their support by the same poles is imperative.

The problem is not merely engineering and constructive, it is commercial as well. The lines are often owned by different companies, and there is apt to be controversy in which self-interest regarding methods of procedure and matters of cost and responsibility take precedence over good engineering on the one hand and public safety on the other.

This involved technical and commercial situation has been handled in a broad-gauge way by the National Electric Light Association. Its committee on overhead construction presented at the last convention a report of nearly 200 pages, covering specifications for overhead lines for 2 300 volt service, and for secondary voltages; also an inter-company agreement form and specifications for the joint use of poles by lighting and telephone companies. This is followed by specifications for overhead crossings of electric light and power lines, which is a joint report of committees of the National Electric Light Association, the American Institute of Electrical Engineers, the American Electric Railway Association, the Association of Railway Telegraph Superintendents, and the American Railway Engineering and Maintenance of Way Association. The report has the endorsement of the leading telegraph and telephone companies. The names of the fifty members composing these committees are sufficient guarantee of the technical and commercial ability which has been applied to the solution of this problem, and the report itself indicates a broad-gauge view in which high grade practical construction is proposed, avoiding the too-cheap on the one hand and the theoretically elaborate on the other.

It is a significant fact that there has been so wide and intelligent an endeavor to come to a practical agreement. It means much for the companies themselves, for the higher standard of electric service, and for public safety. The 1 000 volt lineman is not to be trusted to run 10 000 or 50 000 volt circuits over telephone wires. It is fortunate that the electrical interests are appreciating this and

are taking action before the public awakens to the hazard which exists in hundreds of houses when commonplace construction is employed where high tension lines cross the telephone circuits which enter these houses.

CHAS. F. SCOTT

Synchronous Phase Modifiers

"A synchronous phase modifier," according to the recently revised Standardization Rules of the American Institute of Electrical Engineers, "sometimes called a synchronous condenser, is a synchronous motor, running either idle or under load, whose field excitation may be varied so as to modify the power-factor of the circuit, or through such modification to influence the voltage of the circuit." The first of these uses, and a practical and convenient means of calculating the reactive effects involved, are covered in a lucid way in the article by Mr. Nicholas Stahl in the present issue of the JOURNAL. The question of improving power-factor conditions on circuits carrying inductive loads whose effect is to limit the useful capacity of generators, transmission lines and transformers, is receiving marked attention on the part of operating engineers. The second application suggested in the Institute definition is one which may have much significance in connection with transmission work.

The synchronous condenser has its widest field of application in connection with central station and industrial power systems; the conditions ordinarily found in the large high power transmission systems of the present time are such that they operate inherently at high power-factor. A brief analysis will indicate the reasons for these tendencies.

The fundamental factors which make low power-factor objectionable are, first, the fact that when current and voltage are not in phase the former has a reactive component which, while it does no useful work, gives a larger resultant current, whose heating effect increases directly as the square of the amperage; second, when a lagging wattless component of current is present, additional magnetization has to be furnished by increasing the generator field excitation, or by other over-excited synchronous apparatus. Such synchronous apparatus should be connected to the circuit as near as practicable to the inductive load giving rise to the low power-factor condition, in order to relieve both generators and transmission line of the effect of the increased current.

The advantage of having the synchronous condenser carry mechanical load in addition to its wattless load is very generally recognized. This gives rise to applications in industrial plants, such as synchronous motor-generator sets for supplying direct-current power, and various other direct-coupled and belt driven applications. The synchronous motor may readily be designed for self-starting under limited load, but the applications should preferably be such as will fall under the classification of continuous load with minimum starting and stopping. In the case of many central stations, the motor load is not a sufficient proportion of their total load to give serious trouble due to low power-factor. Both here, as well as where a considerable induction motor load is carried, the installation of synchronous motors is to be recommended, wherever operating conditions will permit of their successful application. Where territory is open to campaigns for increased motor load, the use of synchronous motors should result in the development of conditions giving maximum economy of operation both of circuits and apparatus.

In the case of long, high voltage transmission lines, the conditions are different. Some significant facts bearing on this phase of the subject were brought out at the last annual convention of the American Institute of Electrical Engineers. Operating conditions and results were given in connection with three typical high voltage transmission systems, with lines of one hundred and fifty miles or more in length operating at approximately one hundred thousand volts. In each case the charging current demanded by the circuits, due to their high electrostatic capacity, is of such magnitude that the entire kilovolt-ampere capacity of at least one of their large generators is required to supply the leading wattless current when no power load is connected. This load varied in the different cases from thirty-five hundred to ten thousand kilovolt-amperes, depending, of course, on the length of line, operating voltage, spacing, and frequency. A further fact was brought out in one case where, with no connected load, the voltage at the receiving end of the line was several percent higher than at the generating end. The operating conditions of these systems are such that, when carry their usual load, there is little demand for synchronous motors as a source of wattless leading current; in fact, a certain inductive load is needed to compensate for the capacity effect of the transmission lines. Under such conditions, synchronous condensers may be serviceable as a means of supplying an in-

ductive component through adjustment of their field currents for under-excitation.

This leads to the second feature of the synchronous condenser mentioned in the quotation from the Standardization Rules, viz., that of compensating for excessive line drop by neutralizing the lagging wattless component of the current, or even raising the voltage at the receiving end by supplying additional leading wattless current. In the case of overloaded central station circuits, for example, this may be the governing factor, rather than the effect of low power-factor in limiting generator capacity.

In regard to generators, either of two limiting conditions may be involved with low power-factor load; the generator fields may not be designed to take care of heating due to the large exciting current required to maintain normal voltage at low power-factor, or the exciters may be of insufficient capacity to supply the necessary current. The former limitation is inherent in the design and can be met only by providing the machine with more liberal field design; the latter obviously can easily be corrected by supplying increased exciter capacity.

In investigating power-factor conditions in industrial plants, the fact should not be overlooked that frequently low power-factor is due to what is commonly termed "over-motoring the load." While many motor applications require maximum torque for only a short period throughout the cycle of operation, cases may repeatedly be found where individual induction motors are operating at a small percentage of their capacity, thus unnecessarily lowering the average power-factor of the plant. A suggestion that is worthy of consideration was offered by Mr. Albert Walton, in a recent article in the Journal on "The Utility of Portable Indicating Meters," viz., that in many cases, intelligent diagnosis and prescription will result in surprising improvement of operating conditions. In an industrial plant seeking economy of operation, the electric motor is no longer treated as an indeterminate source of power. For each application a motor of certain characteristics is required. Both the induction motor and the synchronous motor should be used where they will operate to the best advantage both in performing the required mechanical work and in their effect on the circuit to which they are connected.

E. R. Spencer

Steam Turbine Design

The article in this issue, under the caption of "The Steam Turbine for Future Work," by Edwin D. Dreyfus, is commended for careful study. The title might lead one to suppose it to be prophetic, whereas, in fact, it is a review of conditions as they are, rather than a speculation on the future, showing that the turbine machines of to-day will fill the demands of the immediate future as is does the present. However, to speculate more distantly, it would seem, with the improvements in domestic electrical apparatus and the manifold uses to which electrical energy may be applied, that the central station in our large cities will reach unheard of proportions. This statement, however, is but echoing the prophecy of the eminent British electrical engineer, Mr. Ferranti, who has just visited us. With the increased capacities of stations will come correspondingly increased capacities of turbines, and single units of 50 000 kilowatts capacity seem within the range of easy possibility.

The future progress of the turbine will go hand in hand with generator development. It is, in fact, due to the latter that the higher rotative speeds have been rendered possible, enabling the construction of turbines of smaller dimensions and better economy, and, further, resulting in machines more reliable in operation because of their relatively smaller structures.

Doubtless, with experience, turbine design will become further simplified, again reducing the cost of construction. At the present time, due to competition there seems to be a deplorable tendency toward the reduction of cost at the expense of quality, which from the designer's viewpoint we hope is but transitory.

The small turbines will perhaps experience greater development than the large units, since their capacities, rotative speeds and market conditions necessitate compromises in construction from the standpoint of the design governing the steam path.

Francis Hodgkinson

THE HOOSAC TUNNEL ELECTRIFICATION

H. K. HARDCASTLE

IN September, 1910, it was decided to electrify the Hoosac Tunnel and approaches including the yards at each end. On May 18th, 1911, the first train was drawn through by electric power, while continuous electric operation of the total traffic was begun on May 27th.

The Hoosac Tunnel is the longest tunnel in the United States, being 25 081 feet long from portal to portal. It pierces the mountain range between the Hoosic and the Deerfield Rivers in the Berkshire Hills, its location and the general arrangement of tracks being shown in Figs. 1 and 2. Where the rock is soft the tunnel is arched with brick, but in the greater part the rock is hard and the walls are bare rock. To drain off the large amount of water en-

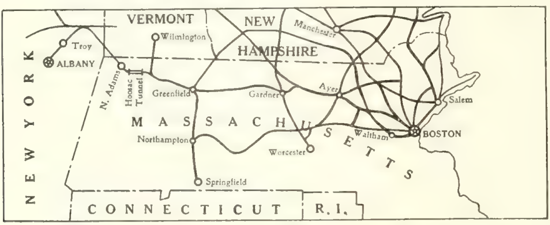


FIG 1—BOSTON AND MAINE RAILROAD LINES IN MASSACHUSETTS
Showing location of Hoosac Tunnel.

countered, the tunnel was run on a grade of 26.4 feet to the mile from each portal to a short level stretch in the center, at which point a 1 028 foot shaft extends to the top of the mountain for ventilation. The work of digging this tunnel was started in 1851, and the first train went through February 9th, 1875. It is straight and double tracked from end to end and cost about twelve million dollars.

The electric zone extends from the little tunnel west of the North Adams station to a point about a quarter of a mile east of Hoosac Tunnel station, the total distance being 7.92 miles. The electrification includes the yards at North Adams, about two miles of the main line between North Adams and the west portal where the grade is about 0.75 percent; then 4.75 miles of the tunnel which

was constructed on a 0.5 percent grade leading from both ends up to the central shaft, and the yards at the east portal, including three-quarters of a mile of main line, having a grade of about 0.5 to 0.7 percent. In all 21.31 miles of single track is electrified.

The traffic at this point has been exceedingly heavy and with the smoke and steam incidental to steam operation, the tunnel has long been the limit of the capacity of the division, besides being exceedingly dirty and disagreeable to passengers. With the tunnel electrified automatic block signals have been installed and the capacity of the tunnel increased three-fold by allowing three trains on

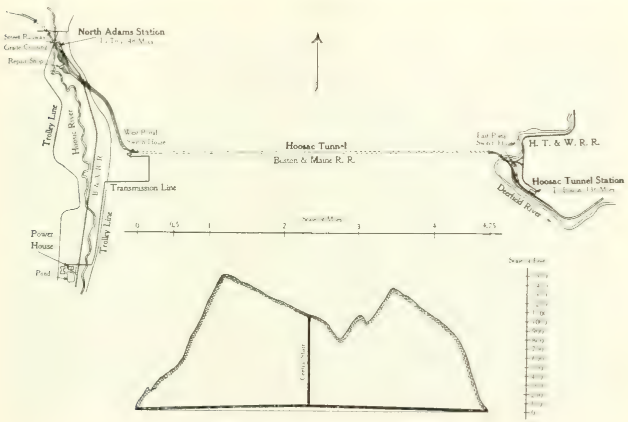


FIG. 2—PLAN AND PROFILE OF HOOSAC TUNNEL

the same track at the same time. This was not safe before, as signals would not have been visible. Instead of being a nuisance the tunnel has become a pleasure in summer on account of its coolness and all passenger trains go through with the windows open.

The method of operation is for the electric locomotive to couple on in front of the steam locomotive as shown in Fig. 3, and pull the train, locomotive and all through the tunnel. Meantime the fires of the steam locomotive are left undisturbed so as to avoid filling the tunnel with smoke and gases. The success of this method is daily demonstrated, for it is usually possible to see out from the central shaft, a distance of 2.37 miles.

Overhead single catenary construction for 11 000 volts single phase was chosen as the system best adapted for this electrification, and the equipment is in many respects similar to that of the New York, New Haven and Hartford Railroad between Woodlawn, N. Y., and Stamford, Conn.

POWER HOUSE

The power house has been built at Zylonite, about 2.5 miles south of the west portal of the tunnel. It is located near the old power house of the Berkshire Street Railway and uses a pond back

FIG. 3—ELECTRIC LOCOMOTIVE DRAWING STEAM LOCOMOTIVE AND TRAIN OUT OF TUNNEL

of this station to supply cooling water for the condensers. From this location it will be possible to supply power to the street railway system without additional transmission lines if it is decided to abandon the old power house, and the station can be used entirely for this purpose if a hydro-electric plant is later built on the east side of the tunnel to supply the railroad. Water for the boilers is furnished by ten artesian wells 100 feet deep, and the coal is brought in from a switch on the Boston & Albany Railroad.

The building is of brick on a concrete foundation 100 by 200 feet and is about 80 feet high. The basement floor is on a level with

the ground, and is divided into three sections. The section at the east end or boiler room basement contains the Worthington duplex boiler feed pumps, the forced draft apparatus consisting of two steam turbines driving Sturtevant blowers, and the ash hoppers and ash cars. The middle section, or engine room basement, contains two Westinghouse-LeBlanc jet condensers, a service pump, the oil filter and gravity oil system, a battery room containing a 120 ampere-hour storage battery, transformers for supplying the lighting system and power for the station apparatus, and a machine shop.

The section at the west end contains the switch house. Here

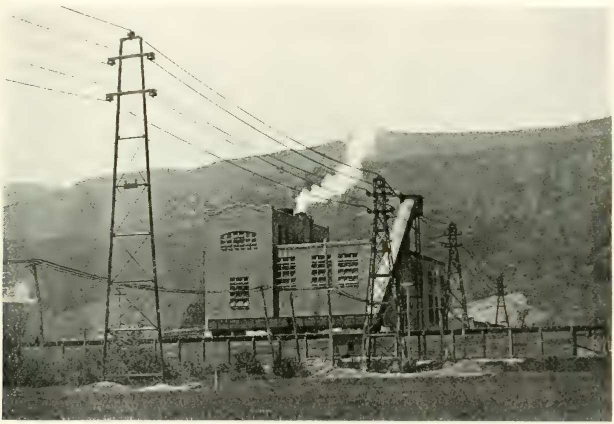


FIG. 4—POWER HOUSE—REAR VIEW
Showing construction of transmission lines.

are located the two 60 000 volt oil circuit breakers, with heavy grid resistance and impedance coils to prevent excessive current during a short-circuit. The grid resistance is in shunt with automatically operated oil switches, so connected as to cut the resistance in series with the line load when a short-circuit occurs. The resistance is of such a value as to limit the current on a dead ground to 600 amperes which the main circuit breaker then interupts, thus completely opening the short-ciruit.

On the second floor is the boiler room, which extends to the roof, and contains four 500 horse-power water tube boilers, equipped

with underfeed stokers, the stokers being operated by a chain belt from the forced draft apparatus. Each boiler is supplied with a superheater which superheats the steam 100 degrees F. The other boiler room equipment includes a Sturtevant staggered tube economizer, two 12-foot induced draft fans, a feed water heater, a feed water weigher, two traveling combined hoppers and weighers for coal, and a service water tank which supplies gland water to the turbines, the jacket water for the compressor and water for the wash rooms. Space has been left in the boiler room for four additional boilers with their necessary equipment.

The coal is unloaded from hopper cars into a receiving bin under a trestle. From this it is raised 75 feet to the roof by a bucket conveyor, shown in Fig. 4, of 40 tons per hour capacity. Here it

FIG. 5—POWER HOUSE AND SPRAY COOLING SYSTEM

passes through a crusher to a 75 ton storage bin. Both the conveyor and crusher are operated by 20 horse-power induction motors.

As mentioned above, there is a pond near the station from which cooling water is taken for the condensers. In order to keep down the temperature of this pond a spray cooling system has been installed. This consists of two sprays or pipe lines about three hundred feet long mounted above the pond, Fig 5, from which the water is pumped through 110 spray nozzles. The water is pumped through the spray system by a centrifugal pump driven by a 100 horse-power induction motor. There is also an engine driven pump for use in emergency. The cooling water for the condensers is drawn in from the upper end of the pond, and discharged through a long flume leading to the lower end. The pumps

supplying the sprays draw water from the discharge of the condensers and what is not used in the sprays goes out through the flume.

Like the boiler room, the engine room extends to the roof. In contains two main units, each consisting of an 11 000 volt, three-phase, 3 750 k.v.a. (single-phase rating) generator coupled to a double-flow steam turbine. The auxiliaries consist of a 100 kw steam turbine exciter unit, a 100 kw motor-driven exciter, a small motor-generator set for charging the storage battery, an air compressor and a 30-ton hand operated crane.

One end of the power house is given over to the switchboard alcove and the rooms containing the remote control switching apparatus, the lightning arresters and the chief engineer's office. The switch board is set at a slight elevation above the engine room floor. It is a dull finish slate board with eleven panels. All 11 000 volt circuits are controlled by oil switches operated from the board by remote control. The generator voltage is regulated by two Tirrill voltage regulators.

A diagram of the electrical layout is shown in Fig. 6. One phase of the generator supplies the trolley load, one phase the power load and one phase goes to ground. The Berkshire Street Railway, however, is supplied by an ordinary three-phase transmission line. For the railway locomotive system there are a set of three-phase station bus-bars and four separate feeder bus-bars which receive power through oil circuit breakers from the main bus-bars. The "trolley" bar of the feeder bus-bars furnishes power for the electric locomotive load and the "control" bar furnishes power to operate the circuit breakers which control the various sections of the track at the west portal and at the repair shop. The "trolley" and "power" lines are protected by an electrolytic lightning arrester, and the "control" line by a low equivalent lightning arrester. The "power" phase of the feeder bus-bar also furnishes power to a feeder for the hand-control operation of the circuit breakers at the switch houses. A reactance coil is located between the main station bus-bars and the feeder bus in the "power" and "control" phase to prevent excessive current during a short-circuit.

This may be made clearer by assuming a short-circuit, say a flash-over of a pantagraph insulator, on one of the locomotives somewhere on the line. The rush of current through the series

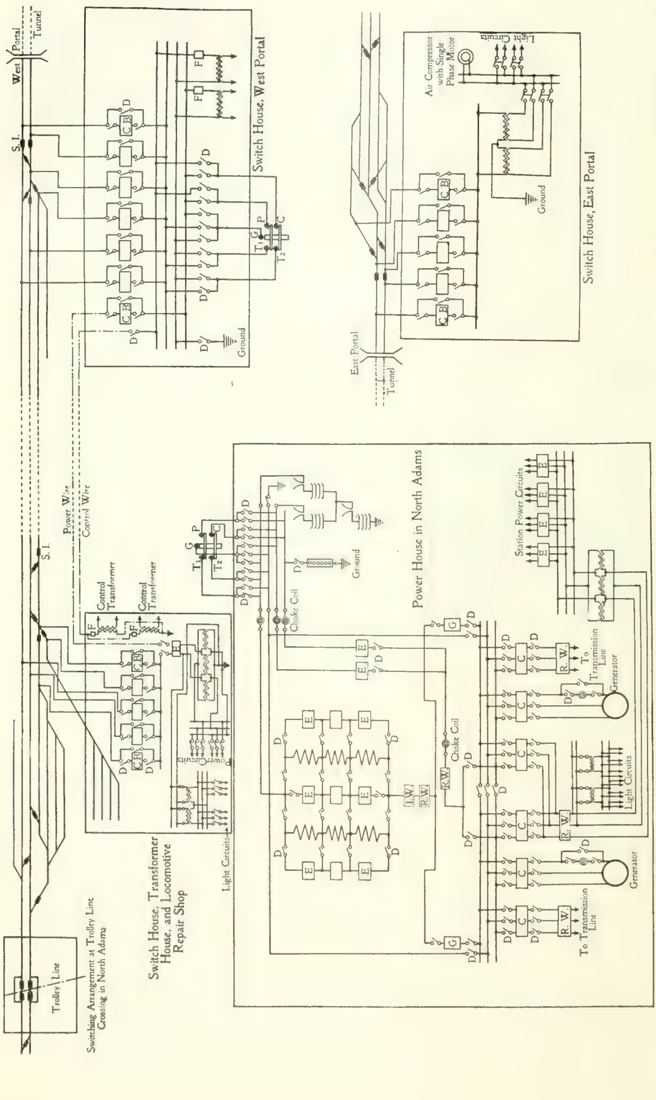


FIG. 6—DIAGRAM OF POWER HOUSE AND SWITCH HOUSES
Showing arrangement of equipment.

transformer in the switch house operates relays which make the connections between the "control" wire and the mechanism operating the section breaker in the switch house which controls that particular section. The section breaker does not open, however, as the control wire is not yet energized. The rush of current then operates an overload relay at the power-house which opens the switches in succession cutting a heavy resistance in series with the trolley phase. At the same time the overload relay has operated a switch which energizes the control wire and thus, as the proper connections have already been made at the switch house, as mentioned above, the proper circuit breakers open to cut off current from this section. If for any reason these circuit breakers at the switch house do not open the circuit at the end of a given interval the switches at the power house will open, removing all power from the trolley phase.

TRANSMISSION LINE

The current is transmitted at 11 000 volts from the power house to the switch house at the west portal over a double circuit transmission line 2.42 miles in length. The corner towers, Figs. 4 and 7, are formed of four uprights made of angle-iron strengthened by angle-iron cross pieces and diagonal braces. These uprights support at their top an angle-iron frame work on which are mounted the porcelain insulators that support the wires. The uprights are set in concrete foundation piers. The towers along the straight part of the line are formed of two eight inch channels connected together by angle-iron braces and diagonals and tied together by a cross piece at the top. These towers carry two angle-iron cross-arms and are supported on two concrete foundation piers set at right angles to the direction of the line. They are spaced about 300 feet apart on the level.

The transmission line consists of five stranded copper cables, two of which carry current for the trolley or locomotive load and are suspended from the cross arms at one side of the tower, while the power and control wires are suspended in a similar manner from the other side. The cross tie at the top of the tower carries an insulator to support the ground wire which also serves as a guard wire protecting the transmission line against lightning. The line terminates at the switch house at the west portal which controls the entire system. The switch houses at the east portal and at the repair shop are not connected to the transmission line, but are

fed through the trolley wires of one or both main tracks. Therefore, as long as current is on either one of the main track trolley wires the remainder of the system can be operated.

The same towers which carry the transmission line also carry two telephone wires supported on one of the cross braces between the channels about ten feet below the high-tension wires. Noise due to inductance on the telephone line is prevented by frequent transposition of the wires, the two wires being turned through 90 degrees between each tower. The effect of inductance is further reduced by one-to-one transformers put in series with the line, one wire being led through the primary and the other through

FIG. 7—VIEW OF SWITCH HOUSE AND OVERHEAD CONSTRUCTION AT WEST PORTAL

the secondary. The static charge is taken off through impedance coils connecting the two telephone wires, the center point of the coils being grounded.

OVERHEAD CONSTRUCTION

Outside the tunnel two different systems have been used to support the overhead line. For two and three track sections on the main line the supporting bridges are built-up trusses of the type shown in Fig. 7, formed of seven and eight inch channel top and bottom chords with light angle posts and double diagonal rod braces in each panel. These bridges are supported at each end by A-frame towers formed of two eight inch channels braced with light angles, the plane of these towers being parallel to the center line of the tracks.

In the yards, where more than three tracks are equipped with overhead wires, instead of the steel bridges, cross catenary span wires are suspended from the apex of A-frame steel towers built of eight inch channels, with their sides in a plane at right angles to the track, Fig. 8. The messenger cable insulators are suspended from these stranded steel cross catenary cables by stranded steel wires of suitable length. Each tower is grounded by a cable clamped to the apexes of the towers. The anchor bridges are box trusses supported on heavy A-frame towers with latticed sides stiffened with double diagonal braces.

The overhead trolley system is sectionalized into twelve units

FIG. 8—CROSS CATENARY LINE CONSTRUCTION IN YARDS AT NORTH ADAMS

consisting of two tracks in the east portal yards; east bound main track and west bound main track of the east portal; east bound and west bound tracks of the tunnel; west bound main track from the west portal to the west end of the North Adams yard; a section of the east bound main track and a cross-over opposite the west portal switch house; two sections of the long siding between the North Adams yard and the west portal switch house; the shop yard; four tracks in the North Adams yard, and the east bound main track from the west end of the North Adams yard to the west portal switch house.

An interesting point in the overhead construction is the crossing of the double track 11 000 volt alternating-current railway trolley and the single track 600 volt direct-current trolley lines of the Berkshire Street Railway, just west of North Adams station.

A view of this crossing is given in Fig. 9. The 600 volt trolley is sectionalized with wooden section insulators eight feet long on each side of the crossing, and is carried over the crossing under an inverted five inch channel which is supported by stranded steel cable span wires. This channel iron is on the same plane as the 11 000 volt alternating-current trolley wires but is insulated from them by similar eight foot section insulators. The direct-current trolley wire in this crossing section normally carries no current. On the north side of the crossing a feeder is connected to the

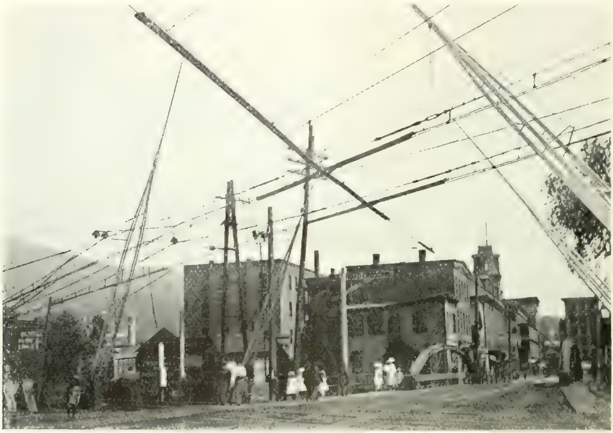


FIG. 9—TROLLEY CROSSING AT NORTH ADAMS

11 000 volts alternating current and 600 volt direct-current trolley wires crossing at same level.

600 volt trolley wire and carried to a switch on top of a wooden pole. When this switch is closed by pushing up on a rod, 600 volt direct-current is fed to the crossing channel and trolley wire so as to permit a street car to pass over the crossing with current on. When the rod is released the switch opens by gravity, and by making another contact, grounds the channel iron and the direct-current section of the trolley. The section insulators in the 600 volt trolley are grounded at the center of their length so that the 11 000 volt current can not leak past them in case of breakdown of any of the 11 000 volt section insulators.

The messenber cable outside the tunnel consists of a five-eighth inch stranded steel cable which supports a No. 0000 grooved copper conductor by rigid hangers of varying lengths at intervals of ten feet. The contact wire, which is No. 0000 grooved Phono-electric, is carried 1.75 inch below the copper conductor by double clips attached in the center of the ten foot spans between the hangers. On curves the conductor and contact wires are both suspended from the messenger by inclined hangers having double clamps.

Inside the tunnel on account of the small clearance and the

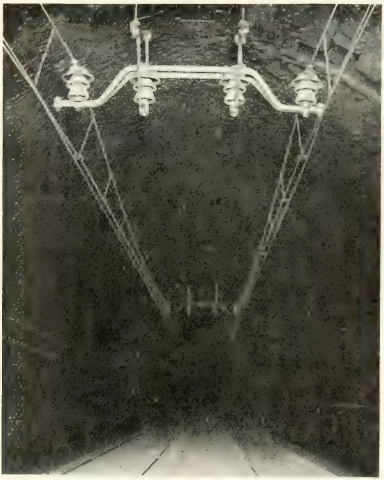


FIG. 10—OVERHEAD CONSTRUCTION IN TUNNEL

great amount of moisture present, the erection of an 11 000 volt trolley presented quite a problem. The supports are 100 feet apart and consist of U-shaped brackets parallel to the track, held in place by 1.25 inch wrought iron bolts extending 18 inches into the rock or brick arch. These bolts were split at the upper end and hammered home on a wedge, but prior to setting the bolts, the holes were filled with cement, and the cement rather than the wedges being relied upon to hold the bolts in place. Two U-pieces support a bracket of the type shown in Fig. 10, by means of two 150 000 volt triple petticoat porcelain insulators and these brackets, which extend across the

track, in turn support the messenger cable through 150 000 volt insulators. As these primary and secondary insulators are in series, the combined dielectric strength is 300 000 volts.

Owing to the limited clearance in the tunnel the two contact wires are lowered to 15 feet 6 inches above the rails. For the same reason the messenger cables are supported 14 inches inside the center line of the track. This gives a minimum clearance of 12 inches between the messenger and the roof of the tunnel. In order to provide maximum conductivity a five-eighth inch stranded copper wire cable is used for a messenger. The twin contact wire hangers are designed to allow some vertical movement of the trolley wires. All parts of the tunnel hangers are made of bronze.

DIFFICULTIES OF THE WORK

The difficulties encountered in erecting the overhead construction in the tunnel without seriously interfering with the traffic must have been seen to be appreciated. The fact that it has heretofore been costing about two dollars to replace a tie owing to the fact that often the men could work only a couple of hours in the whole day, and that it was a common occurrence to have men brought out unconscious, owing to the bad air, may indicate something regarding the conditions in the tunnel.

To reduce the amount of smoke and handle the heavy freight trains during the work of construction, the railroad company purchased four large Mallet compound oil burning engines. The erection work was done by men on two specially constructed work trains each consisting of an oil burning locomotive, two locomotive tenders, a box car containing blacksmith's forges and anvils, an air compressor car, thirteen platform cars on which were built working platforms eleven feet above the rails, a coach fitted up as a dining car and a freight caboose. The trains were piped for compressed air supply and thoroughly lighted by electricity. On the floor of every third platform car a wooden air lock was built into which the men could retreat during and after the passage of a train. An air valve was provided inside these locks which, when partially opened, created sufficient pressure to keep out the smoke and gases, and provided fresh air for the men in the lock.

The construction work in the tunnel included the drilling of 1 000 holes, 2.5 inches in diameter and 18 inches deep, in the roof of the tunnel for the catenary hangers; 1 500 holes 1.75 inches in diameter and six inches deep in the side walls for telephone and

signal cable hangers; the drilling and blasting down of the rock roof of the tunnel in many places to obtain the necessary clearance, and erecting the messenger and trolley wires.

In order to make the working conditions as good as possible the large fan at the top of the central shaft was run continuously, and the two work trains were kept on opposite sides of the shaft with their locomotives coupled to the end nearest the shaft so that the men would not be bothered by the smoke of either locomotive.

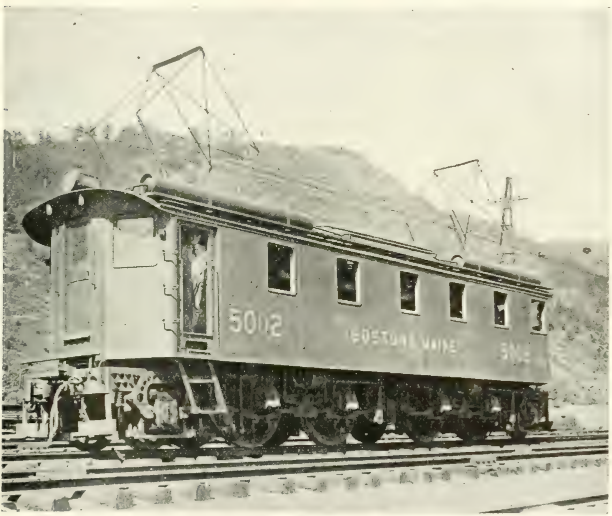


FIG. 11—ELECTRIC PASSENGER LOCOMOTIVE

ELECTRIC LOCOMOTIVES

The electric locomotives were built in the Baldwin and Westinghouse shops. Three of the locomotives are intended primarily for freight service, and have a maximum tractive effort of 67 000 pounds and a maximum speed of 30 miles an hour. The others are intended for combination passenger and light freight service, and have a maximum tractive effort of 40 000 pounds, with a maximum speed of 50 miles an hour. These locomotives are identical with the exception of the gear ratio, and by changing the gears and pinions it would be possible to change a passenger locomotive over to a

freight or a freight over to a passenger. Each locomotive weighs 130 tons, 96 tons of which are on the drivers, and is 48 feet long between couplers, the total wheel base being 38 feet 6 inches.

The locomotives have two articulated trucks, each truck consisting of two pairs of 63 inch drivers with seven foot rigid wheel base, and a pair of radial pony wheels 42 inches in diameter. The trucks are of very heavy and substantial construction. They carry the draft rigging and are connected together by a heavy draw-bar. The cab is supported by four spring loaded friction plates on each truck. One truck center pin is arranged with longitudinal play relative to the cab, thus relieving the cab of pulling and bumping stresses. The power is supplied by four 375 horse-power single-phase motors mounted directly over the driver axles and bolted fast to the frame, thus being entirely spring borne. The power is transmitted from the motor by two flexible gears which divide the load equally and prevent shocks on the gear teeth and also give the motors a chance to start under heavy load. These gears drive a quill surrounding the driver axle with 1.5 inch clearance, and run in bearings in the motor frame. The quill is in turn connected to the wheels by a system of long helical springs which allow the wheel to follow any inequalities in the track without affecting the motor.

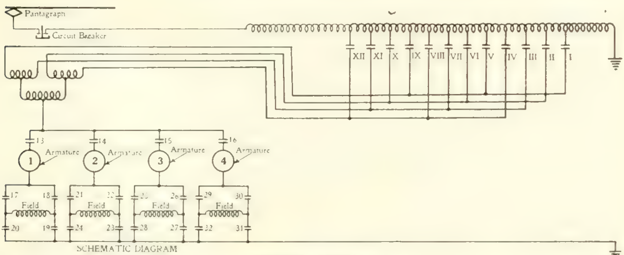
Owing to the short rigid wheel base with the radial lead trucks, the light dead weight per axle, the concentration of weight near the mid length of the locomotive, and the high center of gravity, these locomotives ride very smoothly and are exceptionally easy on the track.

The electrical equipment consists of:—

Four 375 horse-power single-phase motors.
One air-blast auto-transformer.
Two 11 000 volt pneumatically operated pantagraph trolleys.
One 11 000 volt oil circuit breaker.
Three preventive coils.
Four groups of pneumatically operated unit switches.
Two 10 horse-power single-phase motors for driving the compressors.
One pilot governor operating a compressor switch.
Two 7.5 horse-power blower motors.
Two 20 volt storage batteries for operating the magnet valves.
One motor-generator set for charging the batteries.
One speed limit relay.
Two master controllers.
Two temperature indicators for showing the temperature of the main motors.
The necessary control circuits, receptacles and jumpers for multiple unit operation.

With the exception of the main motors and storage batteries which are mounted on the trucks and the pantagraphs on the roof, this apparatus is all mounted inside of the cab, and is so arranged

as to be visible and easily accessible. The motors are of the series commutator type with short-circuited auxiliary field windings. Twelve taps giving different voltages are brought out from the auto-transformer for acceleration and speed control of the main motors. The overload tripping mechanism of the oil circuit-breaker operates in conjunction with a dash-pot which prevents the circuit breaker from opening as a result of momentary surges in the high-tension line. The circuit-breaker is closed by an air cylinder and opened by a spring and the weight of the moving parts when the control circuit to the magnet valve is broken. This circuit is connected through a removable contact plug in the master controller and



SEQUENCE OF SWITCHES

Step	CB	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Off	o																																
1	□	o												o	o	o	o	o		o		o		o		o		o		o		o	
2	o	o	o											o	o	o	o	o		o		o		o		o		o		o		o	
3	o	o	o	o										o	o	o	o	o		o		o		o		o		o		o		o	
4	o	o	o	o	o									o	o	o	o	o		o		o		o		o		o		o		o	
5	o		o	□	o	o								o	o	o	o	o		o		o		o		o		o		o		o	
6	o			o	o	o	o							o	o	o	o	o		o		o		o		o		o		o		o	
7	o				o	o	o	o						o	o	o	o	o		o		o		o		o		o		o		o	
8	o					o	o	o	o					o	o	o	o	o		o		o		o		o		o		o		o	
9	o						o	o	o	o				o	o	o	o	o		o		o		o		o		o		o		o	
10	o							□	o	o	o			o	o	o	o	o		o		o		o		o		o		o		o	
11	o								□	o	□	o		o	o	o	o	o		o		o		o		o		o		o		o	
12	o									o	o	o	o	o	o	o	o	o		o		o		o		o		o		o		o	

For reverse rotation, switches 18, 20, 22, 24, 26, 28, 30, 32 replace switches 17, 19, 21, 23, 25, 27, 29, 31.

FIG. 12—SHEMATIC WIRING DIAGRAM OF LOCOMOTIVE

a contact disc on the overload trip plunger. The plunger latches open when operated by an overload and can be released only by pressing the reset button on the master controller with the controller handle in the off position.

Each of the unit switches in the switch groups is provided with a magnetic blow-out, and is operated by air through a magnet valve and an air cylinder. The main circuit connections and the order in which the switches are closed for acceleration are shown in Fig. 12. The main motors are all connected in parallel, and any motor may be cut out by opening a battery switch in the control circuit to its switches, without affecting the other motors.

An overspeed relay is provided which will automatically disconnect the power lines from the motors at a predetermined maximum speed. This will prevent the locomotives from being accelerated to a speed that will damage the motor armatures, but does not prevent their attaining excessive speed on a down grade. The relay consists of two coils the cores of which are balanced by a rocker arm and carry a contact disc. One coil is energized through a series transformer by the current in a motor lead, and the other by the voltage across the motor armature. The relay disc is normally held away from its contacts by the unbalanced weight on the rocker arm, but when the motor is running at such speed that the coil energized by the voltage across the armature overbalances the coil energized by the decreased current passing through the motor, the relay disc lifts and makes a contact which, through an auxiliary relay, opens the control circuit to the main motor switches.

A very complete shop for the maintenance of the electrical equipment has been built at North Adams. This contains drop pits with hydraulic jacks, well lighted inspection pits, a 15-ton electric crane and machine tools for doing any ordinary repair work.

RECENT DEVELOPMENTS IN SIGNALING FOR ELECTRIC RAILWAYS

HAROLD McCREADY, Asst. Electrical Engineer and C. O. HARRINGTON, Engineer of Materials
Union Switch & Signal Co.

IT is only within the present year that the rapid growth of interurban electric lines in all sections of the country has been met by active developments in signaling suitable for the requirements of this particular character of traffic. While the requirements are essentially those encountered on steam railroads, yet the net earnings per mile of the interurban lines have been so low that usually those responsible for their management have considered the standard signal systems of steam roads as too expensive and have placed dependence on a despatcher or on some simple system of hand-controlled signals. Successive increases in the density of traffic, weight of equipment and the speed of trains have rendered these simple systems inadequate, and it is the purpose of this paper to describe briefly the advances made in electric railway signaling through the application of telephone train despatching, trolley contact signals, and automatic block signals and train stops controlled by the continuous track circuit. The subject is treated principally from the single track point of view, as most interurban roads are equipped for single track operation.

TELEPHONE TRAIN DESPATCHING

Modifications of the simple despatching system have recently been devised wherein semaphore signals under the direct control of the despatcher, are placed at meeting or other important points along the road. The signal stands normally in the clear position and is thrown to danger at the will of the despatcher by a selective relay which responds only to a certain predetermined series of impulses; the selective relays, one at each signal location, are connected in multiple on the line, each relay responding only to its own peculiar number and combination of impulses, as sent out by the automatic calling-key in the despatcher's office. Movement of the semaphore blade to the stop position causes an "answer back" signal to be returned to the despatcher, who then waits for the crew of the train so signaled to "call in." Thus, the despatcher can get in personal touch with the motorman with little delay. The system requires only two wires, but if either of them should break, the despatcher would lose control over all or part of the signal system. Such a system is not automatic nor

does it afford constant protection; it merely facilitates communication betweent hhe motorman and despatcher, made more necessary by the absence of a signaling system. It is comparatively cheap, and, within its limitations, is highly useful.

TROLLEY CONTACT SIGNALS

Much intelligent endeavor and experiment have been directed towards perfecting a system of signals operated by a trolley contact, that is to say a system in which signals, usually a combination of colored discs and lights, are controlled by a contact operated by the passage of the trolley wheel. Signals are placed at the entering and leaving ends of the block to be protected, and the circuit scheme is such that when a train passes a trolley contact at the entering end it automaically clears the signal at that point, if the block is clear, and at the same time throws the signal at the opposite or leaving end of the block to danger so as to prevent opposing moves. It follows, that if a train is already in the block and approaching, the signal at the entering end will be at danger and therefore the train waiting at that point will take the siding to allow the approaching train to pass. When the latter has left the block the signal clears as soon as the waiting train passes the trolley contact, it being understood that in case a signal is at danger the train must not pass the corresponding trolley contact. If, by mistake, the trains passes the contact, a backup movement must be made until the train is back of the contact. Some of these contact systems have ingenious permissive features by means of which following but not opposing moves are allowed; in one of the best known systems as many as fifteen cars may follow one after another into a block, all at once, or they may be continually entering and leaving, and still they will all receive protection. The cars are counted in or out of the block as they enter or leave by relays which operate a ratchet wheel, the wheel being moved in one direction when a train enters the block and in the contrary direction when a train leaves the block. The ratchet wheel operates a revolving switch which controls the discs and lamps giving the indication. While as many as fifteen cars can follow each other into the block, all opposing moves are prevented until all these cars have cancelled themselves out and the revolving switch is in the neutral position. The advantages claimed for the trolley contact system are:—simplicity, the small quantity of apparatus required, small first cost and low maintenance cost. Its disadvantages are serious and are of such a nature that they cannot be remedied. In the first

place, the most important piece of mechanism of the whole system, the trolley contact, cannot be depended on with high speed traffic. Again, if a two car train or a freight train, such as many interurban roads operate, should break in two (an accident which sometimes occurs) the motor end of the train would be counted out and the rest of the train would be left in the block ready for a collision. The system would give no protection in case a rail were broken in the block or if a car were within fouling distance on a spur track. Again, if the trolley wheel left the line before reaching the trolley contact the motorman would pass the signal at night without knowing it, and enter the block without setting the signal at the opposite end of the block at danger, thus leaving himself open to a full speed head-on collision.

CONTINUOUS TRACK CIRCUITS

In the evolution of signaling for steam roads, contact devices have been entirely discarded in favor of the continuous track cir-

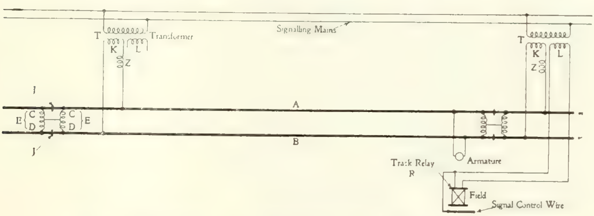


FIG. 1—DIAGRAM OF ALTERNATING-CURRENT TRACK CIRCUIT

cuit. Operating conditions on interurban roads are very similar to those met with on steam roads, for in both instances, first class trains have to be run at high speeds and on frequent schedules. It is a fact worthy of note that all important installations of signals made on interurban roads during the past year have used the continuous track circuit.

Principle of Operation—The principles of the continuous track circuit as adapted to roads using either direct-current or alternating-current electric propulsion may be described briefly as follows:—The road to be signaled is first divided into track sections separated from each other in a signaling sense by insulating joints, as indicated at *J* Fig. 1, but connected for the return of the train propulsion current by impedance bonds *E* which consist of a few turns of heavy strap copper wound around a laminated steel core.

Signaling mains, such as indicated in Fig. 1 which are ordinarily carried on a pole line parallel to the track, serve as a source of current for the transformers *T*. For ordinary conditions of interurban electric railway work, 2 200 volts seems to be the most satisfactory potential for use on the signaling mains. The propulsion return current in the rails *A* and *B* passes in opposite directions through halves *C* and *D* of the bond so that the reactance factor in the return circuit due to the bond is zero even with alternating-current propulsion; thus the bonds introduce into the return circuit only the dead resistance of the strap copper winding, amounting only to a few thousandths of an ohm. The result of this balanced condition is that no magnetic flux due to the return current flows through the laminated core, which therefore has a high permeability for the magnetizing force due to the signaling current. Since the halves *C* and *D* of the bond are in series with reference to the potential of the small track transformer *T*, which feeds current along the rails to the track relay *R*, the bond chokes back the signaling current which, were there no impedance, would flow across from rail and thence through the relay at *R*.

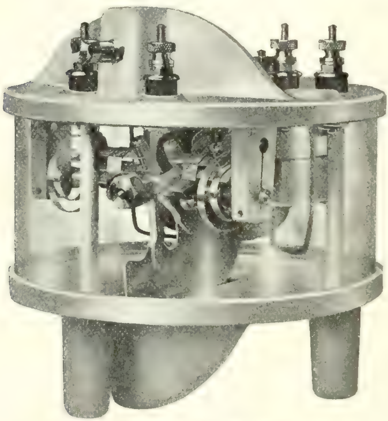


FIG. 2—VANE TYPE RELAY

Track Relay—The relay may be of the single element type, such as that illustrated in Fig. 2, where an aluminum vane, operating the relay contacts, is drawn up into a split magnetic field; or it may be of the double element type as shown in Fig. 3 where an armature, supplied with current directly from the track, works on the galvanometer principle in a field created by two coils connected locally to a secondary coil *L* of the transformer *T* shown in Fig. 1. The single element relay is simple mechanically and is economical of power on short track circuits, but as all the power necessary for its operation has to be transmitted over the rails, the loss

in transmission becomes considerable on track circuits over 2 500 feet in length, at which point the double element relay becomes more economical on account of the fact that most of its power is supplied locally in the field coils, the energy in the armature or track element being very small. The field coils are always energized. Referring further to Fig. 1, it will be seen that when there is no train in the block the relay *R* will be energized, but that when a train enters the block the wheels and axles will short-circuit the relay and transformer (impedance *Z* being inserted in the transformer secondary to prevent the flow of an excessive short-circuit current), and thus power is cut off entirely from the relay if it has only one element, or off the track element alone if the relay has two elements; in either case the relay will be de-energized and the moving member will open the contacts by gravity. The same result occurs in case one of the rails breaks, if a train breaks in two and part of it is left in the block, or if a car projects off of a spur track within fouling distance of the main line. The contacts of the relay will open no matter how fast the train runs. Thus the continuous track circuit affords exact and complete information as to the condition of the block at all times.

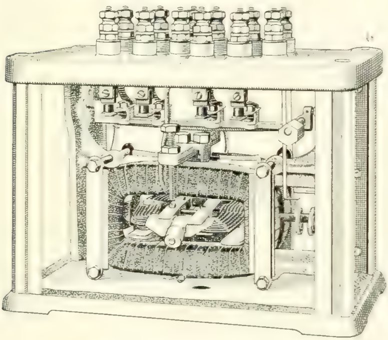


FIG. 3—GALVANOMETER RELAY

Where direct-current propulsion is used the single and double element relays, briefly described above, are of course selective in the sense that they will operate only on the alternating signaling current and not on the direct propulsion current. In those cases where alternating-current is used for propulsion, the signaling current used has a higher frequency than the propulsion current, and the track relay is designed to operate only on the higher frequency. The selective principle is thus maintained.

AUTOMATIC TRACK CIRCUIT SIGNALING

Automatic track circuit signaling makes use of the principles of the continuous track circuit for the control of block signals.

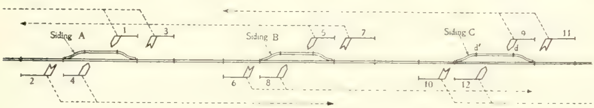
The contacts of the track relay are used to control a signal which indicates a clear track when current flows over the track relay contacts, and indicates danger when the circuit is interrupted by a train entering the block and shunting the relay. The signal may be either of the semaphore type or it may be a light signal. The semaphore signal, in moderately clear weather, can be sighted by a motorman on a high speed train in plenty of time to stop if the signal is at danger or to proceed without slowing down if the signal is at clear. On the other hand, the light signal cannot under some circumstances be seen at such a great distance as the semaphore and consequently the motorman may be obliged to slow down in some cases in approaching a signal, in order that he may be sure of its indication before proceeding further. However, important improvements have been made in the light signal during the last few months and the use of large powerfully illuminated lenses provided with suitable hoods to prevent sunlight reflection, make it possible to distinguish the signal even in bright sunlight, at distances of 1 500 feet. A signal of this type generally consists of a cast iron box, in the front of which are located two lenses, one green to indicate proceed and the other yellow or red to give the caution or stop indication. The lenses are of the Fresnel type, eight and three-eighth inches in diameter, and are each illuminated by two 25 watt tungsten lamps.

Light signals certainly have much to recommend them; they are much more simple and less expensive than semaphore signals and have an additional advantage in that there are no exposed moving parts to be interfered with by sleet or ice. In view of the advantages offered by the combination of the light signal and the continuous track circuit in the way of simplicity, efficiency, and low first cost, the reasons for installing less reliable systems involving trolley contacts, etc., disappear.

Siding Protection—The application of the continuous track circuit, and signals controlled thereby, to siding protection and curve protection is illustrated diagrammatically in Figs. 4 and 5, where for the sake of clearness the impedance bonds, track transformers and relays have been omitted. The signals are displayed on the right hand side of the track in the direction over which they govern, the indication being in the upper or lower left or right hand quadrant as desired but here shown in the upper left hand quadrant. Referring to Fig. 4, the home signals *1, 4, 5, 8, 9* and *12* with pointed blades are absolute and must never be passed in the

danger position, except when the train is preceded by a flagman through the block, as may sometimes be necessary in case the signal should get out of order. Distant signals *2, 3, 6, 7, 10* and *11* with forked blades are permissive as they simply indicate whether the home signal is at clear or danger, which knowledge is of great value with high speed traffic in case the home signal cannot be seen because of its location around a curve, or because of trees, fog or other interference. If the distant signal were not there the train would have to slow down until the motorman could see the home signal. The distant signal and in turn the home signal goes to danger the moment a train passes it, and in this manner complete rear end protection is afforded.

The dotted lines in Fig. 4 show the limits of control of the signals, or in other words the track circuits which govern their



FIGS. 4 AND 5—SIGNALING FOR SINGLE TRACK ROAD WITH PASSING SIDINGS, AND ARRANGEMENT OF SIGNALS FOR CURVE PROTECTION

operation. It will be seen that a train approaching siding *C* from the right passes signal *11* which movement has no effect on signals *6* and *8*, as they are controlled only to signal *9*; a train passing signal *9* however will block the opposing train at signal *8* because this signal (as well as its distant signal *6*) goes to the stop position as soon as signal *9* is passed. In the other direction a train passing signal *6* will cause signals *9* and *11* to assume the danger position. Should trains pass signals *6* and *11* simultaneously the train which passed signal *11* would be held at signal *9* until the train passing signal *6* had made siding *C*; this result, as may be seen, is secured simply by overlapping the controls of signals *6* and *11*, the short section between signals *6* and *8* acting as a preliminary or setting section to prevent opposing trains from passing home signals simultaneously. For ordinary meets, say from the right, the first train arriving takes the siding *C*, the other train stopping at the home

signal *12* at the far end of the siding until the signal clears due to the first train being within the electrically insulated section *dd'* of the siding. As soon as signal *12* clears, the second train passes and the first train backs out of the siding, restoring the main line track switch to the normal open position before the train can proceed. The requirement that trains shall always back out of sidings not only precludes the possibility of the hand operated track switches being left open, but allows of the sidings being used for storage of freight cars, for loading and unloading, etc.

Curve Protection—In many cases on long tangents, block signals are not necessary, but in all cases dangerous curves must be protected against head-on collisions. The scheme shown in Fig. 5 affords absolute protection; the curve is located between signals *1* and *2* which are usually placed about 2 000 feet from the beginning of the curve. A preliminary or setting section about 1 500 feet long extends from signal *1* to point *3* so that two trains running in opposite directions cannot each claim the right of way as a result of their having passed signals *1* and *2* simultaneously. The scheme of operation is as follows:—a train approaching from the right passes point *3*, the beginning of the preliminary section, and immediately signal *2* goes to danger so that a train approaching from the left will be held at signal *2*. The first train continues past signal *1* in the clear position, with the assurance that there is no train between signals *1* and *2*. However, the fact that signal *1* is clear does not mean that the track is clear to the next siding, and in rounding a curve thus protected a motorman must always have his train under control prepared to stop at the opposing signal as a train may be waiting at that point.

The above is a brief description of the scheme of control such as installed on the Illinois Traction System, a large and important line operating 460 miles of single track, where the train operation is typical of interurban roads with heavy traffic on fast schedules. On each division the daily service includes hourly passenger trains of one or two cars in each direction running alternately as locals and limiteds, two scheduled freight trains and an average of four express or merchandise trains in each direction. Over 65 miles of automatic electric semaphores controlled by continuous track circuits are in operation and have given such satisfactory results that additional signaling is being constantly installed.

Similar systems have been installed recently by the Northwest-

ern Pacific and the Southern Pacific railroads in California, and by the Rochester, Syracuse & Eastern, the Syracuse, Lake Shore & Northern, and the Auburn & Northern Electric Railroad in New York State. A contract has recently been let by the New York, Westchester & Boston, a new single-phase electric road, running North and East out of New York, which employs the 11 000 volt, 25 cycle propulsion and a signaling system consisting of automatic blocks with continuous track circuits operating high frequency track relays in much the same manner as on a similar system which has been in successful operation on the New York, New Haven & Hartford during the past four years. The subways in New York, Philadelphia and Boston and the great Pennsylvania Terminal in New York, as well as the West Jersey & Seashore R. R. and the Long Island R. R. are all equipped with outomatic block signals and continuous track circuit control.

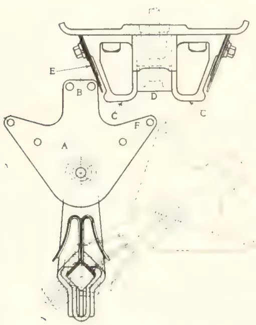
AUTOMATIC TRAIN STOP

To prevent the disregard of danger signals by intent or accident, the automatic train stop has been used for several years on certain subway and elevated lines where heavy trains must be run at high speeds with a minimum headway. The automatic stop works in conjunction with the signal system so that when a danger signal is displayed and an attempt is made to pass it, the train stop operates a valve in the train air brake system and opens the train line, thus bringing the train to an absolute stop.

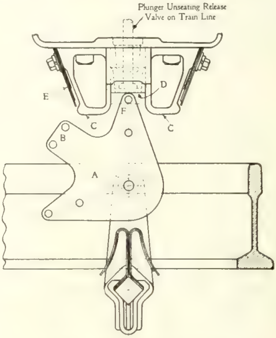
The latest design of automatic stop, illustrated in Fig. 6, is of rugged construction peculiarly adapted to the heavy service imposed by fast trains. The stop comprises two principal parts, a tripper arm mounted on the roadway near one rail and a valve underneath the car which can be operated by the tripper to set the brakes. The tripper arm is mounted on a rocker shaft operated by a solenoid magnet or by compressed air, so that the arm may be forced down again the ties. When the signal is clear and a train approaching, the stop magnet is normally de-energized and the tripper arm then occupies the vertical position illustrated. At the end of the arm is pivoted the trip *A*, Fig. 6, constructed of two butterfly shaped pieces of pressed steel so bolted together as to secure great strength with the least possible weight and inertia; this trip is held in position by two opposed helical springs which however give it flexibility and allow it to be easily deflected in either direction.

The trip is shown standing in the normal or stop position, the dotted lines showing the position of the arm when the stop magnet is energized; with the trip standing in the stop position its tip *B* is directly in line with the anvil *C* in front of the stop valve *D* underneath the moving car; the anvil *C*, or rather the cushion spring *E* in front of it, strikes the top of the trip which causes one wing *F* to rise and unseat the air valve *D*, thus setting the brakes. Fig. 7 shows the position just as the brakes are being applied.

This design of stop is now in service on the Pennsylvania Tunnel & Terminal installation in New York. It has two decided merits which are lacking in earlier types—the tripper itself is light and flexible, offering the best possible resistance to the stiff blows



Tripper arm set to stop train.
FIG. 6



Tripper arm applying brakes.
FIG. 7

AUTOMATIC TRAIN STOP

to which it is subjected, and brake valve *D* is so placed between the anvils *CC* that it can only be operated by the wing *F* of the trip, any obstruction on the roadway being forced out of place by anvil *C* without touching the valve *D*. Experience with earlier types of stop not equipped with the flexible tripper has shown that the impact from fast trains was sufficient to break arms of the heaviest construction.

There is some apprehension that in the open country snow and ice would interfere with the operation of the stops illustrated in Fig. 6, and for such service the construction may be changed to bring the stop and tripper above the car. It is unnecessary to enlarge on this design, as the principles involved are the same.

To secure full protection against a rear end collision it is necessary to prevent a following train from entering a block already occupied. The automatic stop as described will apply the brakes at the entrance to this block but cannot prevent the train from running some hundreds of feet past the danger signal before the brakes bring it to a stop. It is accordingly necessary to provide what is known as an "overlap" circuit, by means of which a train is always protected in the rear by two danger signals, one at the entrance of the block in which the train is running and the other at the entrance of the first block in the rear. Then a train may safely overrun the first danger signal, the brakes stopping the train before the occupied block is reached.

Where automatic stops are used it is necessary to provide some means of allowing a train to pass a signal which is out of order and standing at danger; for this purpose a key is sometimes provided whereby the conductor may close the stop circuit after the train has come to a stop and allow the train to pass without setting the brakes. To preserve the efficiency of the system it is advisable to keep a record of all attempts made by motormen to pass signals at danger; this may be done by sealing the stop valve or fitting it with a counter which records the total number of times that the valve has been opened.

GENERAL

A poor signal system is worse than no system at all, as it may give false indications leading to a wreck; it will also be the cause of numerous delays and a source of constant expense.

A good block signal system is not only of value in assuring the safety of trains and passengers, but it is also a profitable investment in that it increases the earning power of the road by making it possible to operate heavier trains at smaller headways, beside saving delays at meeting points and curves. Passengers realize that a road equipped with block signals is safer to travel on than a line not so equipped, and will generally give preference to the signaled road. Signaling is a good advertisement, a profitable investment and a great time-saver.

THE SPOKANE AND INLAND EMPIRE RAILROAD

G. B. KIRKER and L. S. HASKINS

THE Spokane and Inland Empire Railroad, which is one division of the Inland Empire System in Eastern Washington and Idaho, is a 6 600 volt, single-phase, 25 cycle road and has been in operation since October, 1906. The other divisions are the Coeur d' Alene & Spokane Railroad, a 58 mile 600 volt direct-current interurban road, and the Spokane Traction Company, operating 52 miles of city street tracks. The superintendent of transportation is in charge of both the Inland and Coeur d' Alene Divisions and both are operated under standard steam railroad rules. The office of the chief despatcher is located in Spokane, from which all train orders are issued. The regular despatching is done by telegraph, although each train equipment includes a telephone by which communication may be had with the chief despatcher at half-mile intervals by means of jack-boxes. One roadmaster has charge of the right of way of both divisions, and one master carpenter has charge of all bridges and buildings.

TRACK AND RIGHT OF WAY

As may be noted from the outline map in Fig. 1, this line is in the shape of an inverted "Y" running south from Spokane with a junction point at Spring Valley, 40 miles distant; the eastern branch running to Moscow, Idaho, the west branch to Colfax, Washington. Excepting the streets of Spokane, the right of way is the property of the railroad. The track is laid with 70 lb. rails of standard gauge, and is ballasted throughout with gravel, the total length of track being 127.5 miles. Both rails are bonded with concealed bonds.

Leaving the terminal building in Spokane the first two and one-half miles are double track, and operated by 600 volt direct-current power while the balance of the road is single track and operated by 6 600 volt, single-phase, 25 cycle power. The territory traversed by this railroad is of peculiar formation necessitating numerous curves, grades and bridges. The longest tangent is a little over two miles in length, and there are several 12 degree curves. The longest piece of level track is one and one-half miles, but this stretch contains four reverse curves of from four to eight degrees. The maximum grade on the main line is two per-

cent equated four one hundreths per degree of curvature, the longest haul at two percent being seven miles. These curves and grades makes the operation and service more severe on the equipment than on other electric roads.

The bridges are constructed of wood and vary in length from 50 to 1 000 feet, the longest bridge, which is shown in Fig. 2, being 135 feet high at the span. Quite a number of the longer bridges are built on curves. There is one short wood-encased tunnel.

OVERHEAD CONSTRUCTION

On the single-phase section single catenary construction, suspended from mast arms, is used throughout, the messenger cable being carried on petticoat insulators. The line construction and arrangement at a siding is shown in Fig. 3. The trolley is 000 grooved hard drawn copper. After four years' service a piece of this wire from a point approximately 12 miles from Spokane showed a wear of 0.004 inch.

The overhead construction is maintained by a motor car crew consisting of one foreman, three lineman, one ground man, one motorman, and one brakeman. These men also do rail bonding and new construction incident to new sidings, etc.

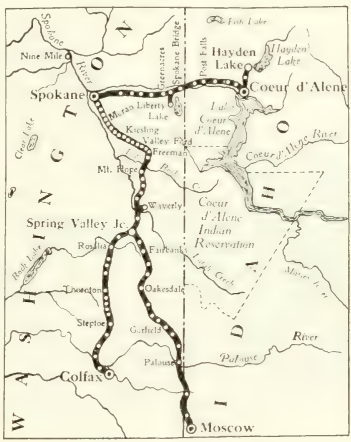


FIG. 1—OUTLINE MAP OF INLAND EMPIRE LINES

ROLLING STOCK

The business of the company has been growing rapidly, necessitating frequent additions to the rolling stock. At present there are five 72 ton freight locomotives; six 52 ton freight locomotives; four combination mail, baggage and express motor cars, 50 feet in length, each weighing 88 500 lbs.; seven baggage and smoking pilot motor cars, 59 feet long, each weighing 94 600 lbs.; four intermediate passenger motor cars, 56 feet long, each weighing

92 600 lbs.; one standard private car; six trailers with observation compartments, 60 feet long, each weighing 64 000 lbs.; one motor car similar to combination car especially equipped for line maintenance; 204 box cars; 158 flat cars; 18 ballast cars; ten stock cars; six refrigerator cars; two steam shovels; one steam ditcher and two steam switching locomotives.

POWER

Power is developed in a hydro-electric power station located on the Spokane River, nine miles from Spokane. This station is

FIG. 2—BIG ROCK CREEK BRIDGE

This bridge is 1 000 feet long, 135 feet high, and is built on a curve 23 miles south of Spokane.

owned by the Inland Empire System and furnishes power for the Spokane & Inland single-phase road, for two 1 500 kilowatt synchronous motor-generator sets that supply part of the direct-current demand of the Spokane Traction Company and the Coeur d' Alene road, and for approximately 1 000 k.v.a. industrial load. Both of these direct-current lines operate for the most part upon power purchased from the Washington Power Company under a contract which has several years yet to run, but upon its expiration the Nine Mile plant will doubtless furnish power for all the roads.

As shown in Fig. 4, the power house is built in the bed of the river as a part of the dam, being so located that the former bed of the river forms the tail race. The height of the dam above the tail race is 58 feet; it is 67 feet thick at its base and is 225 feet long, exclusive of the power house, which is 110 by 85 feet long, and rises 87 feet above low water mark. The lake formed by the dam is over five miles long.

This plant contains four duplicate units consisting of 3 000 kw, three-phase, 60 cycle, 2 200 volt, 200 r.p.m. water wheel generators direct-connected to 5 000 horse-power turbine-type water wheels; four three-phase 3 000 k.v.a. step-up transformers, 2 200 volts delta to 60 000 volts star with grounded neutral; appropriate switchboard, remote controlled oil switches, lightning arresters and choke coils. The 250 volt exciters are direct-connected to the water wheel shafts. A storage battery and motor-generator set has also been installed to furnish direct-current for control purposes, because of the flunctuations of the exciter voltage produced by the Tirrill regulators. A large water rheostat is provided by means of which full load may be placed on the turbines in case the governors should fail to act, thus holding them down to speed.

FIG. 3—MAIN LINE AT MORAN SIDING

Showing present type of catenary construction and 45 000 volt single-phase transmission line.

Twin transmission lines transmit the power to Spokane at 60 000 volts, three-phase, 60 cycles.

During the initial operation of the Spokane & Inland Railroad, current was purchased at 60 cycles. This necessitated a frequency changing station at Spokane. As the single-phase railway load is only a small part of the capacity of the Nine Mile station, and as the

prevailing distributing voltage in this territory is 60 000 volts, 60 cycles, and the frequency changing station was already available, it was deemed advisable in developing the Nine Mile station to transmit at that frequency and voltage rather than at the 25 cycles utlimately used.

SUB-STATIONS

The frequency changing station, a view of which is shown in Fig. 5, contains four units, each consisting of one 1 000 hp three-phase, 60 cycle, 4 000 volt wound secondary induction motor, one 1 000 kw, single-phase, 25 cycle, 2 200 volt generator, and one 750

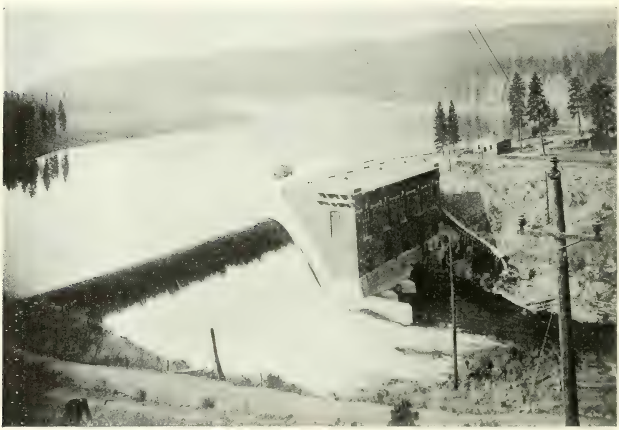


FIG. 4—NINE MILE POWER STATION

Located on the Spokane river nine miles from Spokane. 125 miles of the Inland Division are operated from this plant, as well as two 1 500 kw railway motor-generator sets and approximately 1 000 k.v.a. industrial load.

kw, 550 volt direct-current generator, all rigidly connected on a common shaft and bedplate; two booster sets with carbon regulator; one 2 000 ampere-hour railway type storage battery. This battery the boosters, and 750 kw direct-current generators act as a flywheel, storing energy during periods of light 25 cycle load, and then operating inverted as direct-current motors to assist the induction motors during heavy 25 cycle loads. This station delivers power directly to the alternating-current trolley and to a 45 000 volt, single-phase transmission line carried on a separate pole line parallel

to the track and feeding the various transformer sub-stations.

There are ten transformer sub-stations, including the one located within the frequency changing station. These are situated on the right of way, approximately 12 miles apart. The line is sectionalized with circuit breakers situated near each sub-station, so that each section is fed from two stations, except the southern end of the eastern division. This section is fed by the trolley only from Palouse, Washington, to Moscow, Idaho, 14 miles. The trolley wire normally is electrically continuous from end to end.

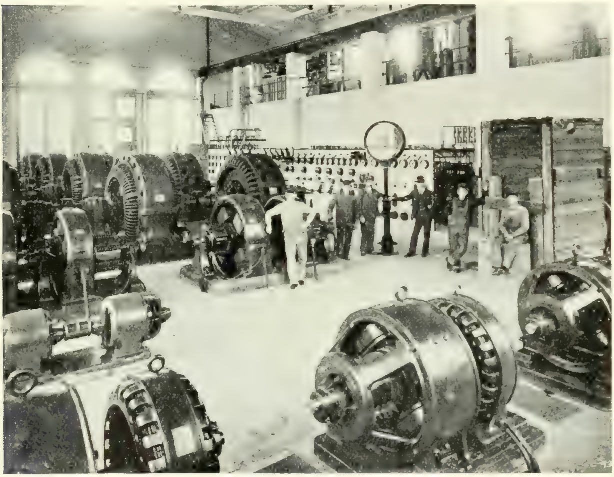


FIG. 5—FREQUENCY CHANGING STATION

Motor-generator sets in background and booster and regulator sets in foreground.

The substations are of brick and contain two or three 375 k.v.a. single-phase, 25 cycle, 45 000 to 6 600 volt, oil-insulated self-cooled transformers. The 45 000 volt line feeds each station through an oil circuit breaker, the transformers having disconnecting switches in both high and low tension leads, while the station is protected by two oil insulated self-cooled choke coils, disconnecting switches and low equivalent lightning arresters. On the secondary side the transformers are grounded permanently to the rail on one polarity. The other leads from their disconnecting switches feed the station 6 600 volt bus-bar through oil circuit breakers. Feeders

through oil circuit breakers protected by air-cooled choke coils, disconnecting switches and low equivalent lightning arresters, feed to each side of the line circuit breaker.

The station ticket agent acts also as substation attendant, using the transformer room as sleeping quarters. Each circuit is equipped with a bell alarm to indicate the tripping of the breaker, and no delays have been chargeable to open circuit breakers during the past two years.

Early in 1910 the Colfax sub-station was submerged, due to

FIG. 6—72 TON FREIGHT LOCOMOTIVE
Photograph taken on test tracks at Wilmerding, Pa.

flood waters in that section. Some months later, after cleaning out the refuse without tearing down the transformers, one of the three units burned out. This is the only substation transformer failure experienced.

FREIGHT EQUIPMENT

There are two daily scheduled freight trains, one to Moscow, the other to Colfax. Each makes the round trip leaving Spokane at night and returning the following day. There are also one or two daily extra freights depending on the amount of business, which do local and extra work between Spokane and Spring Valley

Junction. The locomotives average 20 000 miles per month, the ton-miles closely approximating 3 000 000.

The 72 ton locomotives, Figs. 6 and 7, are equipped with four 175 horse-power geared motors with electro-pneumatic control. Forced ventilation is used for the motors and 6 600 volt auto-transformers. These locomotives handle a 315 ton train at approximately 12 miles per hour on a two percent grade. Their maximum speed is 27 miles per hour. They are frequently double-headed.

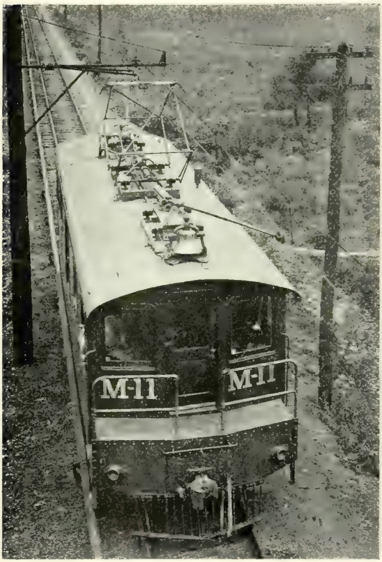


FIG. 7—TOP VIEW OF FREIGHT LOCOMOTIVE SHOWING TROLLEY AND PANTAGRAPH CONSTRUCTION
Photograph taken on the tracks at Wilmerding, Pa.

The 52 ton locomotives are equipped with four 125 horse-power geared motors with electro-pneumatic control. Forced ventilation is used for the motors but the 6 600 volt auto-transformers are oil-insulated self-cooled. When double-headed, as shown in Fig. 8, these locomotives handle a 450 ton train at approximately 17 miles per hour on a two percent grade. their maximum speed is 30 miles per hour. During the past year no motors have failed in service on these locomotives.

The majority of sidings and transfer yards are on maximum grades. At two points, Freeman and Palouse, where a large amount of switching is done, frequently lasting over an hour at a time, the conditions are particularly severe, the grades being two and one-half to three percent and the curves six degrees.

The southern end of the Colfax division was recently reballasted, the gravel being taken from the pit five miles from Spokane. Frequently during this work all the locomotives were in service and

with two gravel trains, the local freight and usual passenger service on the Colfax division at the same time, no difficulties due to low trolley voltage were encountered.

Freight trains are delivered to and taken from the freight yards by the electrical equipment. These trains are made up and distributed by steam locomotives, because the Inland tracks are the only ones in the freight yards that are wired, and on account of the difficulty in using the ordinary direct-current trolley pole over so many frogs and crossings.

PASSENGER EQUIPMENT

All motor cars are equipped with four 100 horse-power geared motors and electro-pneumatic control. No forced ventilation for

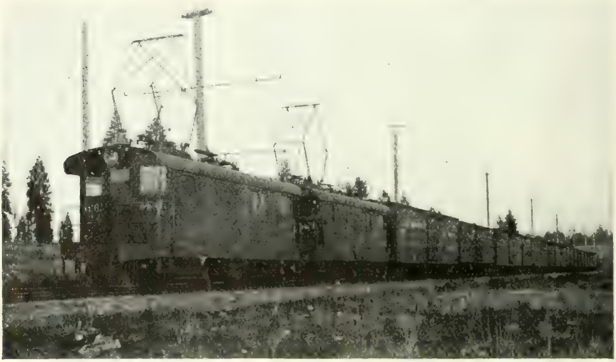


FIG 8—TWO 52 TON LOCOMOTIVES HAULING FREIGHT TRAIN UP A TWO PERCENT GRADE

either motors or transformers is employed. The cars are equipped with pantagraph trolleys for use when on the alternating-current section. Ordinary pole trolleys are used when operating on the direct-current trolley wires in the city streets, and these are insulated sufficiently to be made available for emergency operation on the alternating-current section by the use of an oil switch.

There are 22 daily trains. Eight trains run between Spokane and Freeman, 19, miles, making eleven regular stops and being subject to 15 additional flag stops. These trains are composed of a single double-ended intermediate motor car. Two trains run between Spokane and Rosalia, 46 miles, making 15 regular stops and

being subject to 25 additional flag stops. These trains are composed of two motor cars.

Six trains run between Spokane and Moscow, 90.4 miles. Of these two are made up of a combination mail and express motor car, a pilot motor car and one trailer. They make 20 regular stops and are subject to 24 additional flag stops. The other four of the Moscow trains are made up of a pilot motor car and a trailer. They make 19 regular stops and are subject to 20 additional flag stops. The remaining six trains run between Spokane and Colfax, 77 miles. Of these, two are made up of a combination mail and express motor car, a pilot motor car and one trailer. They make twenty regular stops and are subject to 39 additional flag stops. The other four are made up of a pilot motor car and trailer. They make 20 regular stops and are subject to 21 additional flag stops.

The schedule speed for all of these runs is 30 miles per hour, the trains making on an average 50 percent of the flag stops and through some sections all of them. Between Spokane and Spring Valley Junction there are 38 scheduled stations, from the Junction to Moscow 28 stations, and from the Junction to Colfax 23 stations. All of these (89), with 15 exceptions, are on grades, curves or at the ends of grades, so that is will be seen that the starting conditions are very severe.

The average monthly mileage for all passenger motor cars during the past year was 53 000 miles. Approximately 26 days service per month is expected of each motor car. Two of the cars, however, were in daily service through November and December, 1910, and January, 1911, 92 days, each making 8 500 miles. One motor car was in daily service for 52 days, making 250 miles per day during December, 1910, and January, 1911. During January, 1911, on all motor cars and locomotives there were but three electrical failures, which caused delays aggregating 64 minutes. During the same period three mechanical failures caused delays aggregating 55 minutes. No delays occurred due to line or power troubles. During April, 1911, there was only one delay caused by failure of electrical equipment. It was caused by an old brush shunt coming loose and grounding the motor. This delay of 15 minutes was caused by the motorman's inability to locate the trouble promptly. During the first six months of 1911, there were 24 delays caused by electrical failures, aggregating 752 minutes.

The winter of 1909 and 1910 was one of the most severe experienced in this vicinity. The Spokane & Inland was the only

local road that maintained its regular scheduled service through this trying period. Before the first train went through in the morning there would frequently be twelve inches of snow on the level, and six to seven foot drifts in the cuts. With only a sheet iron sheathing over the pilot of the motor cars for a snow plough, the longest delay due to snow over a three months period was 20 minutes. A train, just after its arrival in Spokane, is shown in

FIG. 9—FIRST TRAIN IN FROM THE SOUTH AT THE SPOKANE TERMINAL, WINTER 1909-'10
Twenty minutes late on account of the snow.

Fig. 9. Little or no trouble was experienced with the electrical equipment due to its being continually snow encased.

The train crews are recruited from men who have had previous experience on steam railroads. The motormen must have had four years experience as locomotive engineers. The conductors and brakemen must have had three years experience. The motormen first spend from two to three months working with the inspection crews at the shops. They must pass an examination in transportation rules, then serve as apprentices to other motormen in regular service until reported by the regular men as competent to handle the equipment.

MAINTENANCE OF EQUIPMENT

The shops are located in Spokane, in a building 200 feet long by 90 feet wide. Forty feet of the width is devoted to the machine shop, and two pit tracks where heavy repairs, motor changing and similar work is cared for. Thirty-six and one-half by seventy feet is taken up by the blacksmith shop and armature rooms. A brick partition separates this aisle from three pit tracks for inspection and storage.

The machine shop does all the machine work for the Inland Empire System, 22 men being employed. There are three blacksmith forges situated adjacent to the shops and a small foundry which casts most of the details in iron, brass and aluminum.

A chief winder has charge of the armature room, his men doing railway work for the Coeur d' Alene and Inland Divisions and also any repairs needed at the power or substations of all divisions. There are also two inspection crews, a day and a night gang, each with a foreman who reports to the general foreman. Each of these crews is divided into two gangs, one composed of two men for heavy work, such as raising cars, taking out motors, wheels or gears, or such other work as is done when a locomotive is sent to the back shops. The other crew of four men do general inspection and make small repairs, etc. There are also two general utility electricians who help the inspection crews or do special repair work of all kinds other than that cared for by the winders.

The passenger equipments are given a light inspection after approximately every 700 miles. The locomotives are inspected after each trip. The inspection crew also do all switching of equipment in the shop yards, and frequently take equipments to the terminal, a mile and a quarter distant. They also do all repair and inspection work on the Coeur d' Alene division.

The brake equipment is maintained under the direction of the machine shop foreman. The repairs to freight cars are made by a gang in the freight yards under the direction of the chief freight car inspector, and a fully equipped paint shop cares for the cars and locomotives of the entire system.

SOME NOTES ON THE BUILDING OF A MODERN RAILWAY MOTOR

C. B. AUEL

Assistant Manager of Works, Westinghouse Electric & Mfg. Co.

NO piece of electrical apparatus has been perfected to a greater extent during the past ten years, mechanically and electrically, than the railway motor. If further improvement is to be expected, it must be in the matter of details to meet special operating conditions rather than in any radical changes in design or in construction. The increasing severity of modern requirements and the demand for light weight motors have led to the use of higher grade materials for castings, gears, pinions, etc., to the adoption of impregnated coils both for the field and the armature, to the use of bearings either of bronze alone, or of bronze or malleable iron shells with thin linings of best quality babbitt and to other equally important changes, all with the sole aim of insuring continuity of service and minimum cost of maintenance. It is not the purpose of this article to enter into an exhaustive analysis of the construction of a modern railway motor, but simply to describe a few of the principal operations in the building of one, with a view to showing some of the methods pursued by the Westinghouse Electric & Mfg. Company, including the system of inspection employed on this class of apparatus.

As is well known, railway motors may be logically divided into two types, "split", and "solid" or "box"; but, since the same general methods are followed in the building of both, a description of one will in large measure apply to the other.

UPPER AND LOWER HALF FIELDS

Milling—The first operation is that of milling both halves of the motor, although occasionally planing may be resorted to instead. There is no particular advantage, so far as the finished product is concerned, in either method. If it be a quantity proposition, as is usually the case, milling will prove the cheaper, since it is much the quicker after the mill has been properly rigged for the work; if, however, but two or three motors are involved, planing will probably be the cheaper, in that less time is required to rig the machine. In milling, the cutter is generally supported in the mid-

dle, as shown in Fig. 1. Were this not done, the cutter would have a tendency to spring upward when milling the ends of the half fields where the castings are thickest, and to bow downwards while milling the center portions where the sides are thinnest. In consequence of this, the half fields when bolted together would show an appreciable air-gap in the magnetic field, sufficient to permit the entrance of water or to produce an increase in speed

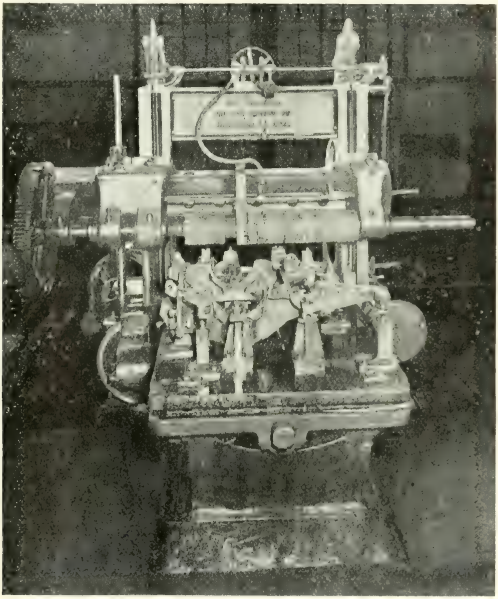


FIG. 1—MILLING HALF FIELD

above normal. To guard against the effect of such springing of the tool and also to give a smooth finish to the faces of the castings as well as to provide a better clamping effect when the half fields are bolted together, the milling cutter is made several thousandths of an inch smaller in diameter than standard, toward both ends and is passed over the fields twice. As a result, when the two halves are finally assembled, the clearance between them never exceeds 0.008 inch. When milling, sufficient material should be

removed so that in the subsequent operation of boring the field with the halves bolted together, the cut will be deep enough to face off the poles smoothly and without leaving any rough spots on them.

Drilling of Parting Line Bolt Holes—The second operation is that of drilling the parting line bolt holes; that is, the holes by means of which the two halves as well as the axle caps are

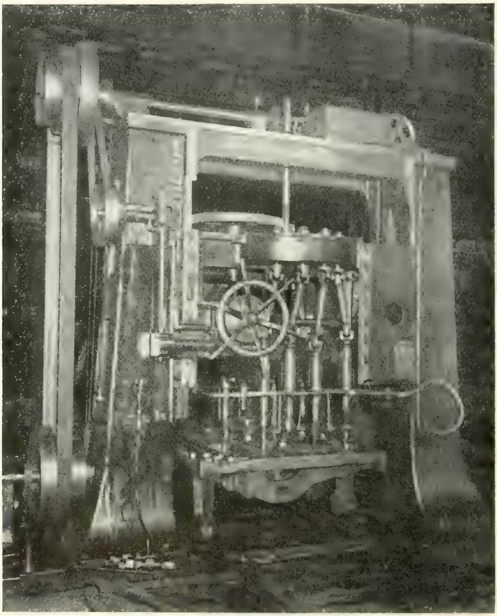


FIG. 2—DRILLING HALF FIELD

bolted together. These holes are practically always drilled to a jig, thus insuring interchangeability of parts. In drilling, due precaution must be exercised to lay out the holes centrally, not only with reference to the poles in the direction of their length, but also with reference to the housing core or bore. The holes are drilled 1/32 inch larger than the diameter of the bolt for clearance. Fig. 2 shows a half field in the process of drilling.

Spot Facing of Parting Line Bolt Holes—Immediately after being drilled, the holes are "spot faced," a spot around the edge of each hole being smoothed off with a tool much like a drill, known as a counterbore, in order to permit the bolts to lie flat against the casting instead of bearing upon it at one portion only. The bolts used in holding the two half fields together are specially finished, not only in the body but under the head which is provided with a small round shoulder, to insure solidity of contact.

Laying out Fields—The half fields are next laid out for the armature and the axle bores. The castings are placed upon a

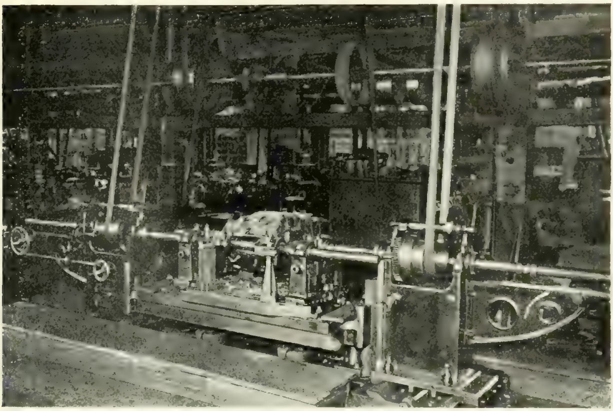


FIG. 3—BORING FIELD FOR ARMATURE AND AXLE BEARINGS

surfacing table and very carefully gone over by an experienced mechanic who, with the parting holes already drilled, as a base, marks off by means of suitable templates and a straight edge, the location for both bores. Due caution must be observed that there is not only sufficient material to permit both bores to be cut clean; but, also that the axle bore does not cut into the magnetic circuit, and that the armature bore does not cut away too much of any of the poles, so as to leave insufficient stock for the field coils.

Milling and Drilling of Axle Caps—The axle caps are first filled with kerosene oil and allowed to stand for one hour, in order to test for porosity. Such as show slight leaks are either electrically welded or hot galvanized. They are next milled, then drilled

and the holes spot faced, these various operations being performed in much the same manner as on the half fields, the bolt clearances also being the same.

Armature and Axle Bores—The upper and the lower half fields and the two axle caps are then fitted together and bored for the armature housings and for the axle bearings; pieces of sheet steel called "shims" 0.012 inch thick are placed between the half fields before boring, thus enabling a clamping fit to be obtained on the armature housings and axle bearings when the motor is finally assembled; at the same time the ends of the castings are faced off so that the bearings and the housings will when placed in their re-

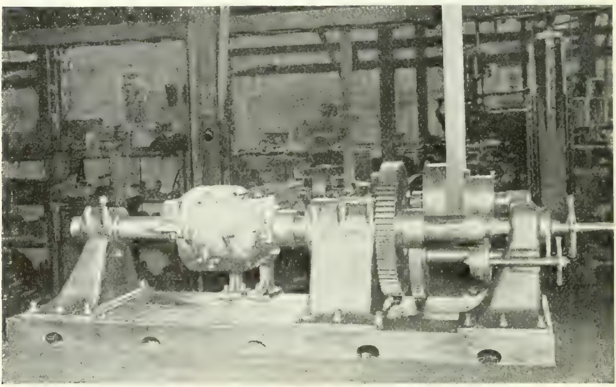


FIG. 4—BORING FOR ARMATURE

spective positions, fit properly at the flanges. In both of the bores accuracy is determined by means of a pin gauge; that is to say, each bore is made so that a pin gauge equal in length to the exact diameter will, when placed in the bore, resting on one of its ends, either fit exactly or else have a rocking movement not to exceed a certain amount which will depend upon the diameter of the bore; thus in an armature housing bore of say 18 inches, the rocking movement would not be permitted to exceed 3/8 inch, which corresponds to an allowance in diameter of approximately 0.001 inch over exact size; likewise, in an axle bore of 8 inches, the rocking movement would not exceed 3/8 inch which corresponds approximately to an allowance of 0.002 inch. In the matter of overall length of field, a

variation of 1/64 inch either way is allowed. Fig. 3 shows a field in position in a double horizontal boring mill ready for boring.

Miscellaneous Drilling of Axle Caps—The axle caps are then removed and drilled for the oil box lid; and the keyway for the bearing is either milled or slotted, or else drilled for the dowel pin where a key is not used.

Field Bore—The field is next placed in position on a floor boring mill, as shown in Fig. 4, in order to bore for the armature. Dummy housings with bearings in them, are used to center the field casting on the boring bar. To compensate for wear in the actual

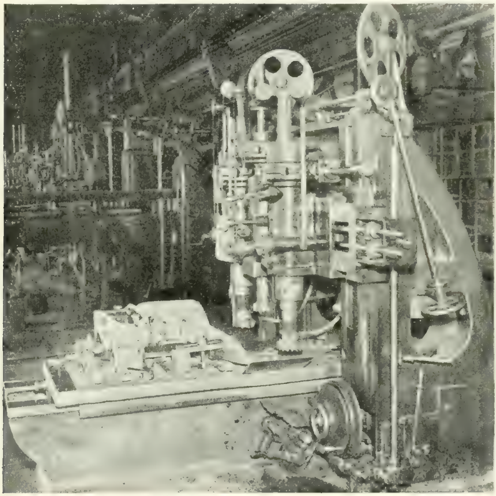


FIG. 5—MILLING GEAR CASE PADS

bearings of the motor, it is customary to locate the armature itself 1/32 inch above the true center. In some types of motor, this is accomplished by having the dummy housings machined sufficiently off center, so that the bearings in them come 1/32 inch above their true center. In other types, the allowance for wear in the armature bearings, is made in the housings actually furnished with the motors. The former method is now the standard, however, on nearly all of the latest designs of motors. The boring bar which passes through the center of the dummy bearings, thus occupies a position 1/32 inch above the center with reference to

the housing bore of the field, in consequence of which, when the field is machined for the armature, the bore of the latter is 1/32 inch above the center of the housing bore.

Milling Gear-Case Pads—A top half field in position for milling the tops of the gear case pads is shown in Fig. 5, the bottoms having been milled at the same time as, and as a part of, the first milling operation. It is essential for the pads to be of such thickness that when finished, the gear case will fit snugly over them, not over 0.010 inch being allowed either way from the exact size, other-

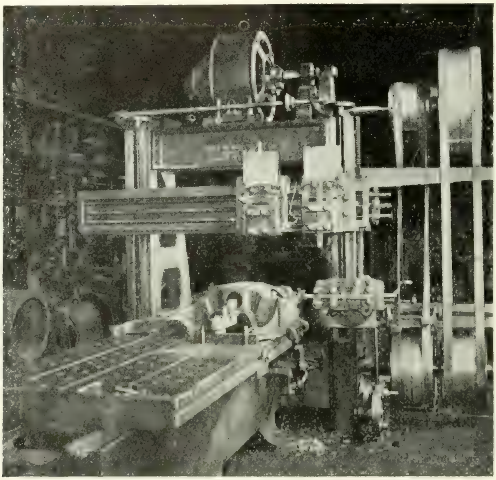


FIG. 6—PLANING SUSPENSION PADS

wise wear and rattling of the parts will probably result after the motor has been in service for a time.

Suspension Pads—In the machining of the suspension pads which may be either milled or planed, planing being shown in Fig. 6, care must be taken to see that the finished faces are not only the proper distance from the center line of the armature shaft, but that they are likewise parallel with a vertical plane through the same center line. A variation of ⅛ inch both vertically and horizontally is however, considered sufficiently accurate for this dimension.

Miscellaneous Drilling—The drilling of a railway motor, other than the drilling of the parting line holes already described, may

be divided into three parts: (1)—Drilling the holes for the pole piece bolts and the housing bolts; drilling the miscellaneous holes,

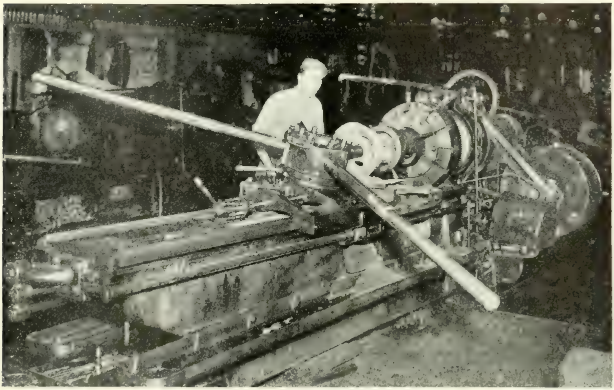


FIG. 7—BORING SPIDER

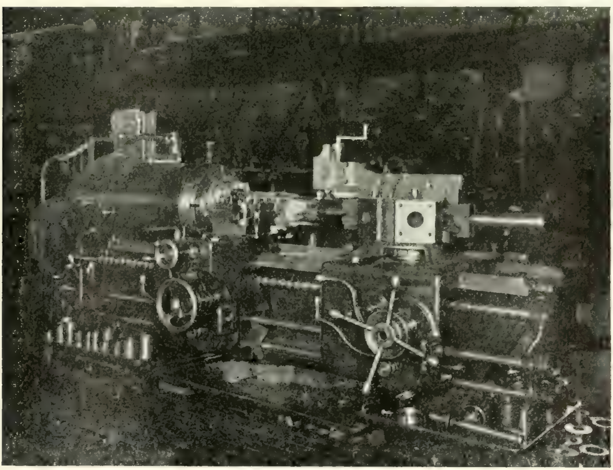


FIG. 8—TURNING SPIDER

with the motor, (2) in a more or less horizontal position, then with it (3) in a similar vertical position, the holes in these last two opera-

tions, including those for the cable bushings, cleats, peep-holes, hand-holes and holes for the oil box hinges. None of these holes except those for the bushings, are spot faced.

ARMATURE SPIDER

Boring—Armature spiders are made either of malleable iron or steel. The end bell is cast as part of the spider proper, instead of being a separate piece; and the laminations and end plates are held in position by a ring nut. The first operation in the machining of the spider is that of boring for the armature shaft, as shown in the lathe in Fig. 7. Three cuts are taken, two so-called "roughing" and one "finishing" cut; after which, if the material is of malleable iron, the bore is reamed for a finish; or, if of steel, a floating cutter is used instead. The former method gives perhaps a little smoother finish; the cost of reamers is, however, not only a considerable item, but this scheme cannot be so well adapted to steel on account of the chips tending to clog the reamer, differing in this respect from either cast or malleable iron. The bore is finished within 0.0005 inch of the required dimensions, the necessary allowance for press fit of the armature shaft being made in the latter.

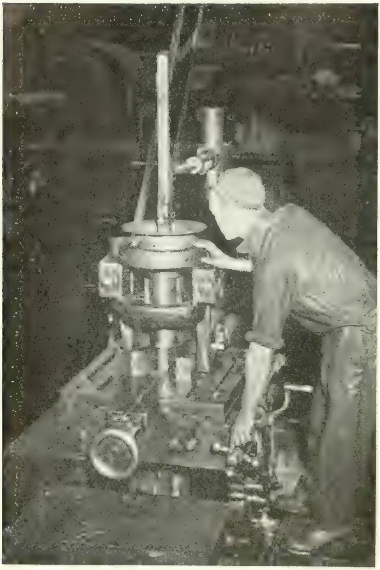


FIG. 9—KEY-SEATING SPIDER

While the spider is in position for boring, the part forming the end bell is turned and faced. The spider is then removed, mounted on a mandrel, placed in a second lathe, as shown in Fig. 8, and the remaining portion of it turned to within 1/32 inch of finished size, this amount being allowed, for subsequent grinding.

Three keyways are next cut in the spider, one on the inside for the armature shaft key, the other two on the outside for the sheet iron laminations and the commutator respectively. These operations are shown in Figs. 9 and 10, the former being known as "key-seating", the latter as "profiling". The keyways are made 0.002 inch under size so that the keys will be a driving fit. The two outside keyways are made at one setting and must be in exact alignment with each other.

The machined spider is then ground to finished size as shown

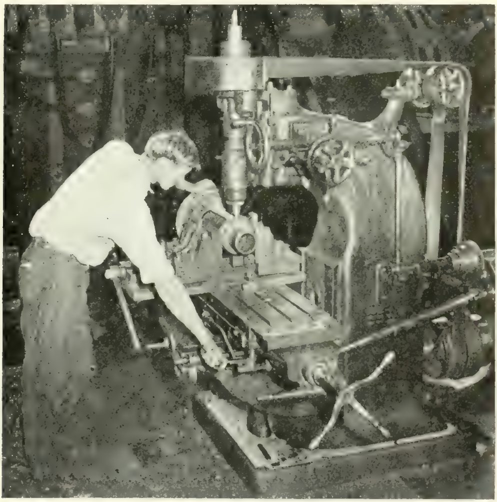


FIG. 10—PROFILING SPIDER

in Fig. 11. In grinding, 0.002 inch is left over and above the exact dimension, so that the laminations will fit tightly when pressed on the spider. A variation not exceeding 0.0005 inch is here permitted.

BUILDING OF ARMATURE CORE

The utmost care is taken to have the laminated iron punchings a tight fit on the spider and, with this object in view, the iron is frequently gauged when being punched, so that any wear in the dies will at once be detected and the error corrected. In building up the laminations, a certain quantity is first weighed, the

amount necessary for each type having been determined by experience. A few sheets at a time are then put on the spider and forced home by means of a hydraulic press, such as shown in Fig. 12. When all of the sheets have been placed in position, the end plate is put on, pressure applied and the armature ring nut screwed down tightly. The pressure of course, will depend upon the size and type of armature, varying from 40 to 60 tons or more. The laminations now used in the building of the core, are so clean-cut that filing has been practically eliminated.

ARMATURE SHAFT

The first operations on the shafts are those of cutting off and centering; that is, the shaft is cut off from the commercial bar

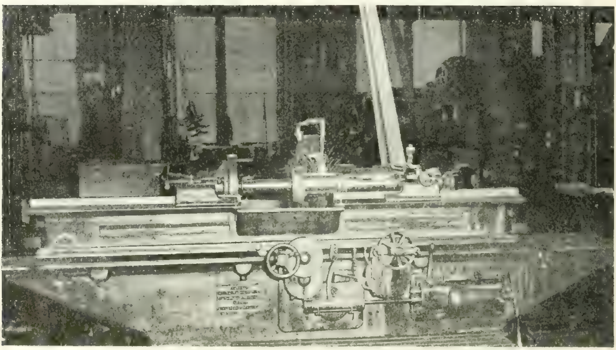


FIG. 11—GRINDING SPIDER

of axle steel to within 1/32 inch of finished length, after which a small cone-shaped hole is bored in the center at each end, to facilitate the turning of the shaft, as well as for convenience in manipulating the armature in subsequent operations.

The shaft is next rough-turned in the body to within 0.020 or 0.030 inch of finished size, and then rough tapered at one end for the pinion after which it is "spotted" for grinding and threaded for the pinion nut. By "spotting" is here meant turning the shaft down to the exact size throughout a small width, at every place where there is a change in the diameter, so that subsequently in grinding, the grinders will have guides to which to work.

Keyways for the pinion and the spider are next milled in the

shaft, very much after the manner in which the keyways are cut in the spider.

The final operations on the shaft as a separate piece of apparatus, are those of grinding the body and the taper, these operations being performed practically like the grinding of the spider.

Miscellaneous—The finished shaft is next pressed into the built-up armature core, as shown in Fig. 13, varying pressures being used, depending, as in the case of the building up of the laminations, on the size and type of motor. For motors of about thirty horse-power, the pressure is approximately 30 tons. The forcing in of the shaft at this pressure has a tendency to expand the spider, thus causing the laminations to bite into it and resulting in a still tighter gripping effect between them. The completed core is finally placed in a lathe, to see that the journals run true with the core; it is then taken to the balancing ways, Fig. 14, and balanced. If any balancing is required, it is done by pouring solder into pockets in the end bell provided for this purpose, access to these being obtained through the medium of small holes made by means of a breast drill. Proper balance is obtained when the core will come to rest in any position, when rolled along the ways.

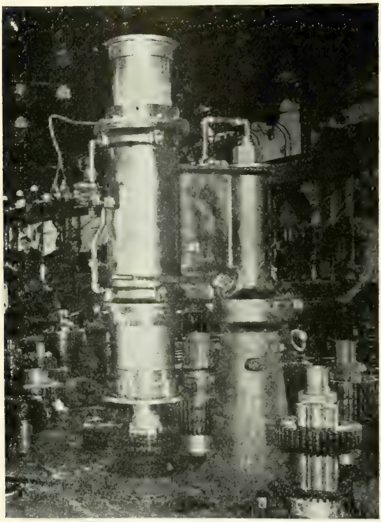


FIG. 12—PRESSING LAMINATIONS

HOUSINGS

Boring and Turning—All housings are of malleable iron and are rough bored, faced and turned at one setting on a vertical boring mill, as shown in Fig. 15. In the machining, a variation is permitted of but 0.0015 inch either way from the exact dimension. In a few types, after the three operations just noted have been performed,

the housing is shifted 0.015 inch off the center in a direction which would be downward were the housing occupying its correct posi-

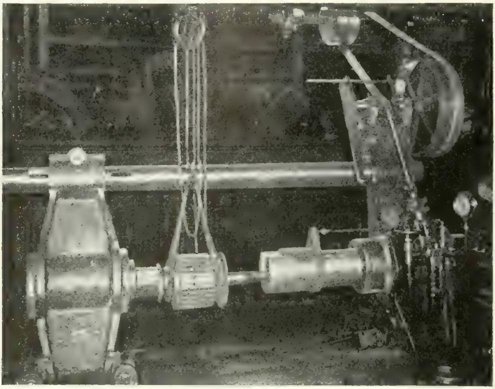


FIG. 13—PRESSING SHAFT INTO CORE

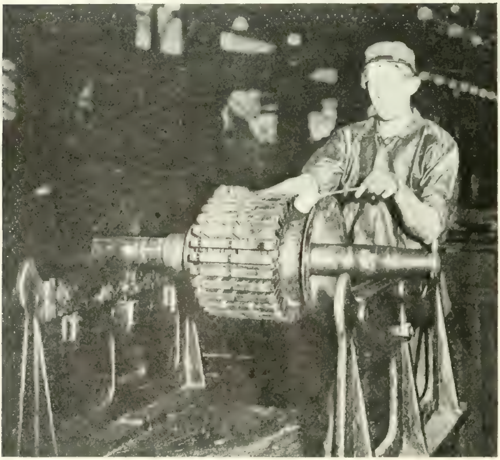


FIG. 14—BALANCING CORE

tion on the motor, and is then finish-bored; in this last operation, a variation of not over 0.0005 inch is allowed either way, This

is to allow for the wear of the armature bearings in service, though as mentioned under the paragraph on "Field Bore," the more usual plan is now to make the necessary allowance in the field instead.

The housing is next drilled and tapped for the bolts which hold it to the field. The keyway for the bearing is then cut, after which the casting is tested for leaks with kerosene oil, in the same manner as the axle caps. To remove dirt which may be adhering to the inside of the oil pocket, and which the intricate shape of the casting may favor, the casting is soaked for one-half hour or more in a solu-

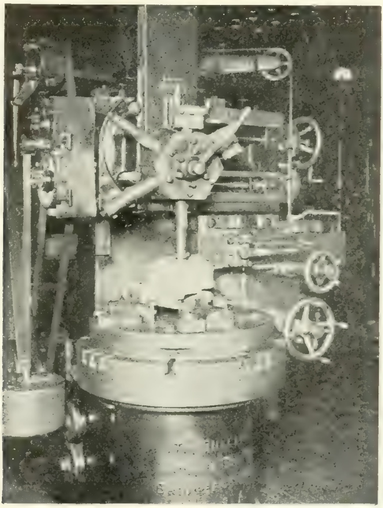


FIG. 15—BORING HOUSING

tion of strong lye. It is then removed, allowed to dry, cleaned with a strong air-blast, drilled for the oil box cover hinges, the cover fitted and the bearing finally pressed into it at a pressure of three to five tons, this last operation being shown in Fig. 16.

POLES

In the making of poles, the end plates, which are of malleable iron, have the holes punched in them, where formerly drilling was the custom. The punched holes are then countersunk. The edges of the end plates are next ground to remove fins, as well as to round the corners. The pole is now ready to be built. The rivets

are placed in one of the end plates, a certain amount of pole laminations is weighed and the individual sheets which, it may be mentioned, are not symmetrical in many of the motors, are reversed with respect to one another, thus providing means for saturating the pole shoes. The laminations are then placed over the rivets a few at a time, until all are in position, the remaining end plate put on, about 60 tons pressure applied and the length of iron measured to see if it corresponds to the drawing requirements. The pole is then clamped so as to hold the iron together, a "double-nut" the function of which is described later, is pressed into position, after which the ends of the rivets, which project about ½ inch beyond the pole, are flanged out under the press, completely filling the counter sunk holes in the end plate. The pole is then squared up, ground at the edges and corners, hand filed, if necessary, and the pole studs screwed into the "double-nut" which thus serves to hold the pole in position when bolted to the motor field.

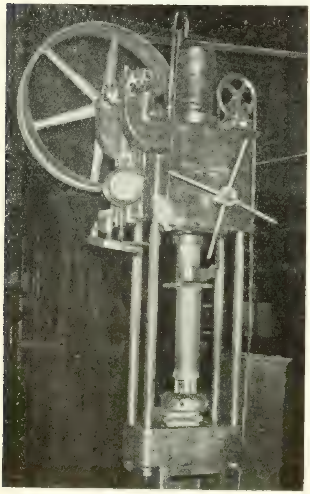


FIG. 16—PRESSING BEARING INTO HOUSING

BRUSH HOLDERS

If any parts of a motor could be said to be of more importance than any other parts, the items selected would undoubtedly be the brush-holders, the commutator and the bearings.

The principal requirements of a good brush-holder are that is shall transmit the current without excessive heating, that is shall not easily get out of adjustment and that it shall be durable. These consideration involve the utmost attention being given to details in all matters pertaining to design, workmanship and materials. The carbons must not only fit the holder within certain well defined limits of accuracy but the carbons themselves must be of a certain quality. The current must pass through the holder and the shunt rather than through the spring, the spring must

have a uniform tension throughout its working range, the entire mechanism must be sufficiently compact so as not to occupy an undue amount of space and the materials used must be selected with a view to resisting rapid wear, etc. Fig. 17 shows the detail parts of a railway type hrush-holder. The holder proper consists of a carefully machined brass casting into which two steel pins are driven and doweled. Upon these pins are placed closely fitting insulating tubes and over them in turn, thin brass shells and porcelain washers. The shells preclude any possibility of damage to the insulating tubes when the brush-holder is clamped in position on the motor, while the porcelains add considerable to the creeping distance, thus preventing grounding from the holder to the brass shells or clamp. The spring mechanism is self-contained, consisting of a punched brass support on which is mounted the phosphor bronze spiral spring with its copper tip, a flexible shunt and a pawl and sprocket, the tip and shunt being insulated from the spring itself. The device is readily secured in the holder by means of a steel shaft placed at right angles to the movement of the spring. The pawl and sprocket enable the spring to be adjusted to the tension required, usually between five and six pounds.

FIG. 17—BRUSH HOLDER AND PARTS

In addition to a careful examination of all parts before assembling, the completed brush-holder is closely inspected. Limit plug gauges are used for testing the size of the slots, a variation of 0.002 inch only being permissible; the springs are tested with a scale for the proper tension; the distance between centers of pins and centers of carbon slots are checked, as well as the position of the slots with reference to the pins, these requiring to be exactly

parallel; finally an electrical test is given, the recommendations of the American Institute of Electrical Engineers being followed in this respect.

COMMUTATOR

A railway type commutator and details are shown in Fig. 18, the building of which may be divided into three parts:—maching of bush and V-ring, building the bars or segments and assembling the commutator. While formerly a great amount of trouble was experienced from so-called "high bars", this has now been practically eliminated, due to improved methods in machining and in building, in the making of the mica and to a greater appreciation of the nec-

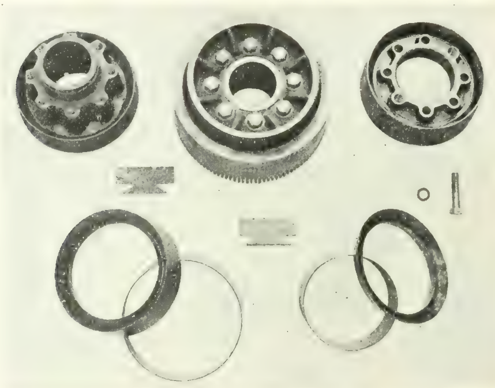


FIG. 18—COMMUTATOR AND PARTS

essity of materials and workmanship being within very narrow limits as regards accuracy.

The copper from which the commutator bars are made must be within 0.001 inch either way of exact thickness. Experience has also shown that it is inadvisable to use punched copper unless finish is allowed for in each V, so that the bars may be subsequently machined. The mica strips may vary from exact size to 0.0015 inch over size. The metal bush and the V-ring are machined to sheet steel templates so that no variation is permitted in them. The mica bush is a loose fit and a certain latitude is thus allowable in it; the mica V-rings, however, are required to be as nearly absolutely uniform as possible and to this end special machinery

has been built for machining them at various stages during their construction.

In building, the bars with the mica strips properly spaced between, are assembled on a temporary bush; they are next baked for a certain length of time and then pressed under heavy pressure into a solid steel ring. Upon cooling, the final machining, previously

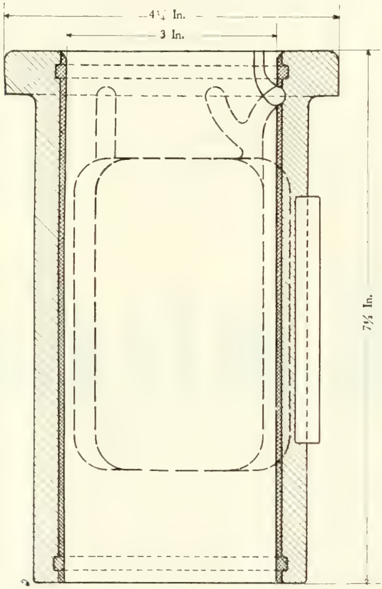


FIG. 19—RAILWAY MOTOR BEARING

referred to, is performed after which the edges of the bars are cleaned up and a careful inspection and test are made for short circuits. The finished parts are now all assembled, the bolts holding them together are screwed down tightly and the ring enclosing the segments is removed. The commutator is next turned to dimensions and again tested electrically, the bars are then slotted for the armature leads, the slots tinned and cleaned and the commutator is given a final inspection and electrical test.

BEARINGS

A one-piece babbitted bronze bearing (3 by 7.5 in.) for a railway motor of moderate size is illustrated in Fig. 19. In the making of bearings of this type the oil grooves are generally cast-in when pouring the babbitt, a collapsible mandrel being used, as shown in Fig. 20. The mandrel consists, as will be noted, of seven pieces, the base, core, four segments and a collar, the last for holding the parts together when assembled. The core and the segments are tapered on their adjacent sides so that after a bearing has been babbitted and the collar removed, the core may be withdrawn, the segments then collapsed toward the center, and in turn taken out. The mandrel is made from 0.004 to 0.020 inch smaller than the finished diameter, depending upon the size of the bearing. While half bearings require slightly different handling, the general procedure is much the same as with solid bearings and a description of the latter will, therefore, suffice for both.

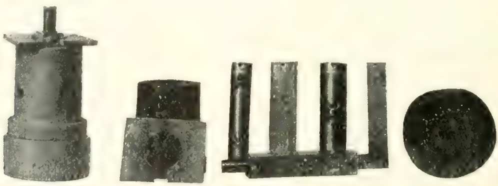


FIG. 20—MANDREL FOR BABBITTING BEARING

The rough casting is first cleaned of sand by brushing, scraping or pickling. If pickled, the bearing especially when provided with anchor holes must be thoroughly dried, otherwise trouble may be experienced in babbitting due to the moisture forming steam when coming into contact with the molten babbitt. The flange of the bearing is next faced, turned and counterbored and the bearing itself is usually bored as well. Of these several operations, the first permits the bearing to lay perfectly flat on the base of the mandrel, the second centers it, while the third and fourth provide the right depth of babbitt at the shoulder and also in the bore. The bearing is next placed over the mandrel, the cored holes are plugged with metal or wood to retain the babbitt temporarily, after which the babbitt is poured. Upon cooling, the plugs and the mandrel are removed and any fins or ragged edges of babbitt are then burned off with a hot soldering iron. The bearing is next broached or bored, after which it is driven upon an arbor to enable it to be

turned in a lathe. The keyway is finally profiled and the bearing may then be considered as completed, provided always it passes the final inspection. As, however, inspection occurs throughout the several operations described and includes several tests daily for quality of the babbitt, this last inspection is comparatively simple, consisting in a checking of all dimensions including length, inside and outside diameters, size of keyway, as well as a careful scrutiny of the general finish.

GENERAL

From the preceding outline of the principal operations on a modern railway motor, it will be appreciated, in some degree, how high must be the grade of workmanship involved and how rigid the inspection, if the standards of quality, as instanced by the examples given. are to be upheld. Throughout the entire railway department, constant inspection is going on to see that all work is performed within the limits of accuracy required. Much of the inspection is done while the parts are actually being machined; and, to insure correctness of measurement, the gauges of the inspectors are not allowed to be used by any other person. While many of the reasons for doing certain operations one way in preference to doing them another, are evident, there are others in which the reasons are not so obvious and in which experience alone has been the guide. Hence, the tremendous advantage which a concern, long established in the manufacture of railway motors has over its competitors. The same experience is likewise, of equal value in the purchase of raw materials permitting, as it does, the drawing up of specifications by the company which serve to advise manufacturers of raw materials as to the quality of goods required. When it is stated that these specifications are regularly filed with the War and Navy Departments of the United States as they are issued from time to time, their importance will be further appreciated.

SOME SPECIAL FEATURES OF 1500 VOLT DIRECT-CURRENT RAILWAY EQUIPMENTS

L. G. RILEY

THE development of the 1 500 volt direct-current system of electric railway service has made necessary the alteration of nearly every piece of apparatus comprising railway equipments, from motors to trolley, and the development of several entirely new details. This is due partly to the increased voltage, which of course requires additional insulation and creepage distances, and partly to the frequent requisite that equipments be arranged for operation at full speed both on 1 500 and 600 volt lines. Facilities for interrupting the main circuits have required particularly close attention.

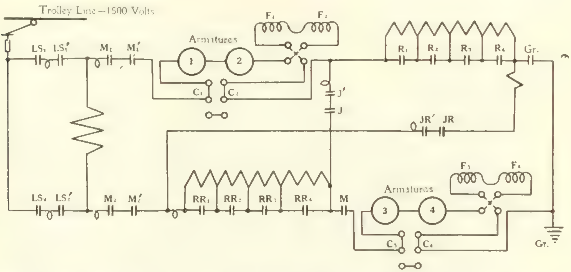
In arranging motors for operation on 1 500 volts the electrical characteristics of the standard 600 volt interpole railway motor have been retained, with little or no change. More space has been allowed for additional insulation on the windings, and for creepage distances between live parts and the frame. The motors are connected permanently two in series so that each individual motor operates normally on 750 volts, although in case one motor slips its wheels, it may have impressed across its armature a large percentage of the entire line voltage. Connecting two motors in series means that series-parallel operation can be secured only with four motor equipments and this arrangement has become standard in the majority of cases, for both cars and locomotives.

The increasing demand for power-operated control apparatus with its advantages of safety and of multiple or train control, in preference to platform controllers carrying the main current, even with comparatively light equipments, makes the application of the unit switch to high potential lines a most advantageous feature. Due to the reduced current required by an equipment of a given rating on the higher voltage, it has been possible up to the present time to use unit switches and other main circuit apparatus of the same capacity as are used with standard hand operated unit switch-control car equipments.* New mountings have been supplied, to

*See article by Mr. K. A. Simmons on "Hand Operated Unit Switch Control," in the JOURNAL for October, 1910, p. 802.

accommodate the increased insulation and allow for sufficient arcing space, but the operating details remain essentially the same.

The schematic arrangement for the main circuits of a locomotive, equipped with four 185 horse-power motors, is given in Fig. 1. This illustration shows the special provision made for handling 1 500 volt direct-current arcs; whereas a 600 volt equipment for the same current would be provided with three unit switches in series with the motors on the first notch, the higher voltage requires a total of seven switches to give the same factor of safety,



	Step	LS₁	LS₁′	LS₂	LS₂′	M₁	M₁′	M₂	M₂′	M	JR	JR′	J	J′	Gr.	R₁	R₂	R₃	R₄	RR₁	RR₂	RR₃	RR₄
Switching	1	o		o	o	o	o			o	o	o											
	2	o	o	o	o	o	o			o	o	o											
	3	o	o	o	o	o	o			o	o	o				o							
	4	o	o	o	o	o	o			o	o	o				o				o			
	5	o	o	o	o	o	o			o	o	o				o	o			o			
	6	o	o	o	o	o	o			o	o	o				o	o			o	o		
	7	o	o	o	o	o	o			o	o	o				o	o	o		o	o		
	8	o	o	o	o	o	o			o	o	o				o	o	o		o	o	o	
	9	o	o	o	o	o	o			o	o	o				o	o	o	o	o	o	o	
	10	o	o	o	o	o	o			o	o	o				o	o	o	o	o	o	o	o
Series Operation →	11	o	o	o	o	o	o			o	o	o	o	o		o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o			o	o	o								
	12	o	o	o	o	o	o	o	o	o					o								
	13	o	o	o	o	o	o	o	o	o					o	o				o			
	14	o	o	o	o	o	o	o	o	o					o	o	o			o	o		
	15	o	o	o	o	o	o	o	o	o					o	o	o	o		o	o	o	
Parallel Operation →	16	o	o	o	o	o	o	o	o	o					o	o	o	o	o	o	o	o	o

FIG. 1—SCHEMATIC DIAGRAM FOR 1 500 VOLT DIRECT-CURRENT LOCOMOTIVE

even with the increased strength of magnetic blowout which has been used. The method of accelerating and of changing from series to parallel closely follows standard practice. Reference to the sequence table will show the switches which are closed on each notch of the master controller. In passing from series to parallel the bridging method of transition, in which full torque is maintained on all motors, has been used.

Where service conditions require that these equipments be operated over 600 volt lines at full speed, it is necessary to arrange the motors to start two in series and two in parallel—the

full speed position on 1 500 volts—and then accelerate to four motors in parallel. In order to secure satisfactory acceleration the starting resistance must also be reconnected, the usual method being to separate individual steps of resistance in two halves, connecting the halves in series for 1 500 volts, and in parallel for 600 volt operation. This is accomplished by means of a drum change-over switch having contact fingers connecting to each of the motor

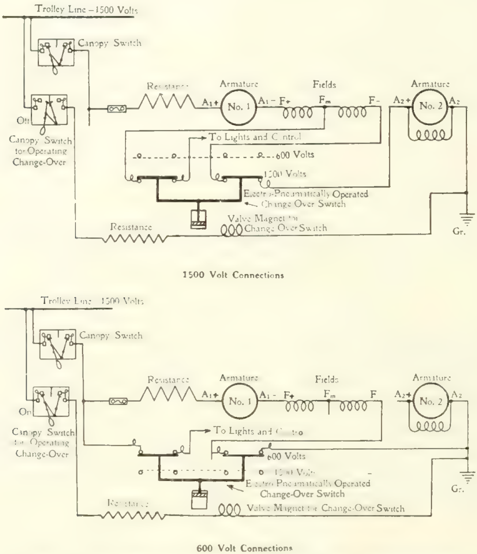


FIG. 2—CONNECTIONS FOR 1 500—600 VOLT DYNAMOTOR

and resistance terminals, and two rows of copper segments on the surface of the drum which are shifted under the fingers by the turning of the drum. The arrangement and shape of the segments are such that one row connects the motors and resistances in their proper relation for 1 500 volt operation, and the other row provides for 600 volt operation. In passing from one trolley voltage to the other this switch is thrown to its proper position automatically or by the motorman. The usual conditions requiring 600 volt adaptation are on interurban roads using existing city lines, and it is

often satisfactory to operate at half speed on low voltages over the city streets. This simplifies the control problem and the operation as well. The equipment illustrated in Fig. 1 is arranged for half-speed operation on 600 volts, and hence no main change-over switch is required.

Safety demands that all high potential apparatus be entirely enclosed and isolated. It is thus necessary to secure reduced voltage for the control circuit, lights, air compressors and ventilating blowers. In order to do this a piece of apparatus known as a dynamotor has been developed, the diagram of connections for which is shown in Fig. 2. As the name implies, the machine is a combined dynamo and motor, but it is not to be confused with or considered as a

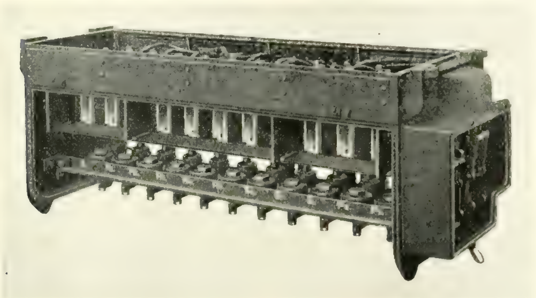


FIG. 3—SWITCH GROUP USED WITH 1 500—600 VOLT DIRECT-CURRENT CONTROL EQUIPMENT UNIT SWITCH

motor-generator set. It is essentially a compound-wound motor, having two independent armature windings, each connected to its own commutator but occupying the same slots in the armature core. A shunt field is added to limit the speed at light loads. The 1 500 volt connections show that the dynamotor operates exactly like two motors in series, and sufficient current is drawn from the connection between the two motors to feed lights and control circuits at 750 volts. This is the dynamo function, and the dynamotor must of course run continuously to supply this load. One end of the shaft extends to a clutch through which connection is made to the air compressor. Instead of the motor circuit being closed by the pump governor in the usual way, the latter is piped directly to

the clutch, which is held open by air pressure when the governor is in the cut-out position. Thus the compressor is operated intermittently through the opening and closing of the clutch under the action of the governor. An extension on the other end of the dynamotor shaft is connected directly to the blower, when required.

Where 600 volt operation is also required a change-over switch is utilized to transform the dynamotor into a motor with only one armature winding in circuit, the other armature winding serving as a generator to sustain the shunt field. The auxiliary circuits are transferred direct to the trolley. A pneumatically operated switch, similar to the operating cylinder of a unit switch, with remote electric control, and provided with suitable contacts, is used for this purpose.

From the foregoing it may be seen that considerable work has been required in connection with the development of the 1 500 volt system, although in general there have been no radical departures from standard railway practice. The detail apparatus, however, will undoubtedly require more rigid inspection than is necessary with standard 600 volt apparatus.

TRAILER OPERATION VERSUS MULTIPLE-UNIT TRAINS*

CLARENCE RENSHAW

THE wide variations in the traffic which a railway must handle at different hours and on different days present a most difficult problem for its management. The traffic apparently demands that the cars be operated on a variable headway, but safety and economy incline toward uniformity. If the cars could only be gradually expanded and contracted, like that piece of hand baggage, the "telescope," formerly so popular among rural travellers, both requirements could be satisfied and such cars would then doubtless be in great demand by interurban roads. Unfortunately the manufacturers of electric railway equipment have not yet been able to produce cars exactly of this type. They have been able to produce cars in which, starting with a given size, the capacity can be doubled, then increased one-half, then one-third, and so on. This method has been used for years on a number of roads under the name of the "multiple-unit" system, and it is only lack of acquaintance with the advantages of this system that has prevented its rapidly increasing use.

A full realization of the advantages of multiple-unit operation can be obtained only on roads having ample sub-station capacity and a liberal feeder system. These are usually found either where a third rail is used as a source of power supply or else where the single-phase system is employed. Almost every road should be able to operate trains of two or even three cars, however, if the size of the cars is properly fixed.

The extent of the variations in traffic which must be cared for at times is indicated by Fig. 1. This shows the number of passengers carried on each trip of a certain interurban line for Saturday, June 3rd, and Tuesday, June 6th, 1911. It shows also how the crowds were cared for by the use of two and three-car trains. The traffic shown for these two days is typical of that for any clear Saturday during the summer and any ordinary week day. The road from which these figures were obtained is single track and is approximately twenty-five miles long. The cars are operated at half-hour headway during most of the day, and as a rule make twelve or fifteen flag stops per trip. The run is made in forty-five minutes. A most interesting feature of this operation is the fact that

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*A paper read at the meeting of the Central Electric Railway Association, at Cedar Point, Ohio, August 23 and 24.

no addition is made to the train crew when two-car trains are operated. The cars have end doors for passing from one to the other and a motorman and a conductor are able to handle easily the heavy traffic shown. When three cars are used, an extra man is added to the crew to assist the conductor. The operation on this road certainly approaches the "telescope" car and serves as an excellent testimonial to the multiple-unit system.

A certain line in the coal regions of West Virginia offers a typical example of a somewhat different class. This road is also approximately twenty-five miles long and single track. As originally put in operation it employed single cars only, seating fifty-six people and equipped with four 75 horse-power motors. The cars

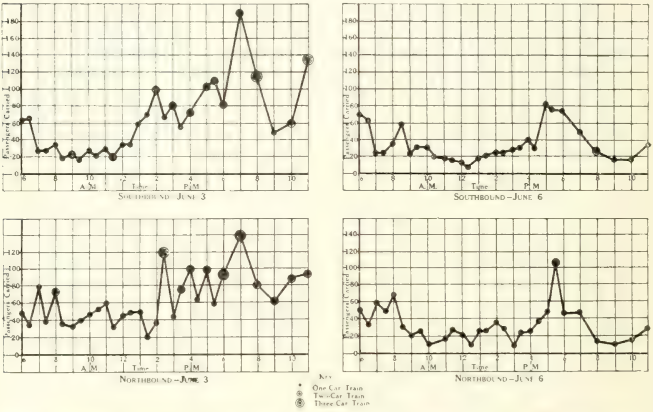


FIG. 1—CHART SHOWING VARIATION IN PASSENGERS CARRIED ON DIFFERENT DAYS

were provided with multiple unit control but had straight air brakes and no draw-bars, so they could not be coupled together. After the line had been in operation several years and the traffic had grown beyond all expectations, draw-bars were added to the cars and the brakes changed to automatic, so that two-car trains could be run. At the same time some additional cars were purchased. These were made somewhat smaller and lighter than the original cars and were equipped with four 50 horse-power motors and hand-operated unit-switch control. When train operation was started, it was found that while it was entirely possible to operate two of the large cars together, it proved to be rather undesirable on account of the load on the sub-stations. With train operation, the

small cars, however, proved a decided success from the very beginning and have become so popular that several more duplicate equipments have since been purchased. Half of the small cars seat thirty-six people, and are provided with baggage compartments. The other half are for passengers only and seat forty-six. A two-car train of the small cars thus provides a baggage compartment and eighty-two seats, as compared with fifty-six seats and no baggage compartment on the single large cars. The train makes the same schedule as the single large cars with equal facility. But, on account of the somewhat lower speed gearing of the motors and the reduced resistance of a two-car train, it takes very little more power. By operating a single small car, a single large car, or a train of two cars, the seating capacity can be nicely graded to suit the traffic.

Many roads no doubt hesitate to employ multiple-unit trains on account of a supposed inadequacy of sub-station and feeder capacity. The requirements in these items can be kept within very reasonable limits by proper training of the motorman. Some years ago a number of tests was made by the writer on one of the early interurban lines in Indiana. The cars were equipped with two 150 horse-power motors, or a total of 300 horse-power each, and were geared for a maximum speed of about 50 miles per hour. Great care had been taken in training the motormen on this line and as a result the maximum current per car rarely exceeded 350 amperes. On other roads, where less care had been taken in instructing the men, currents of over 600 amperes have been noted on cars with only the same horse-power of equipment. It is quite evident from these figures that two-car trains in the hands of the first set of men could have been operated with peaks little or no higher than those caused by single cars in the hands of the second set.

Where multiple-unit trains are employed it is usually not necessary to have either cars or equipment as large as if they were operated singly at all times. In the effort to avoid the operation of other than single cars, the size and equipment of interurban rolling stock has been increased to huge proportions. In many cases these big cars run most of the day with a lonesome dozen or two passengers for the sake of being able to handle the fifty or sixty who must be provided for on a few special trips. To make proper use of multiple-unit trains a size of car more nearly suited to the average load should be employed and the capacity expanded by coupling up when necessary. With

equipments properly proportioned on this basis, there are probably few roads where two-car trains could not be run.

Before the days of the multiple-unit trains, additional capacity was frequently secured by the use of extra sections running on the same time and orders as the regular cars. This arrangement multiplies the difficulties of safe train despatching very largely and in addition requires complete extra train crews. Extra sections are of course sometimes necessary, where cars have not been equipped with train control. As a rule, the dangers of this arrangement are recognized and its popularity for high speed lines is declining.

The principal competitor or perhaps more properly predecessor, of the multiple-unit train, is the combination of a motor car and a trailer.. In obtaining extra seating capacity by the use of trailers, many people seem to feel that they are getting the best of their

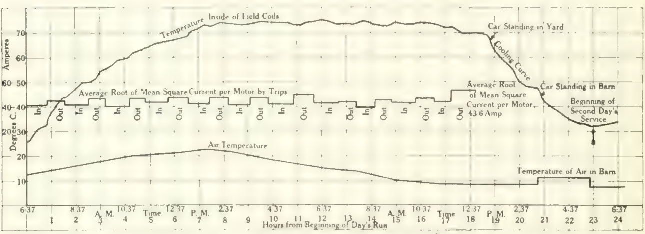


FIG. 2—CURVE SHOWING RISE IN TEMPERATURE OF MOTORS, CAR OPERATING SINGLY

motor equipments, and obtaining extra work out of them without their knowing it. In fact, some even seem to believe that just as the work of the motorman is not materially increased by the addition of a trailer, the work of the motors likewise remains the same. This, however, is far from the fact. It is true that the power taken by a motor car when running at constant speed on level track is increased only a comparatively small amount by the addition of a trailer of the usual proportions, but in starting and accelerating or in propelling the car up grades the tractive effort which the motors must deliver is in almost direct proportion to the weight. In any service, where stops are frequent or grades are severe, the addition of a trailer means a considerable increase in the load on the motors.

In local service, where flag stops are made, as a rule, the greater the number of people carried on any given trip, the greater is the number of stops which must be made. Heavy traffic trips where trailers are employed thus necessitate a maximum number

of stops on account of the greater number of people carried. Even if the trailer had no weight, the extra number of stops is sufficient to make such trips hard ones on the motors (unless they are worked much below their capacity when operating without the trailer) and the use of a trailer under such circumstances, at the very time when it imposes the greatest burden on the motors, is frequently a prolific source of worry for the master mechanic, work for the armature winder and business for the spare part salesman. The effect on the motors of adding a trailer may be seen from the curves, Figs. 2 and 3. These curves are based upon tests made upon single truck city cars*, rather than interurban cars, but nevertheless should serve equally well to illustrate the point. In these tests a coil of iron wire was carefully calibrated in an oil bath and the relation between

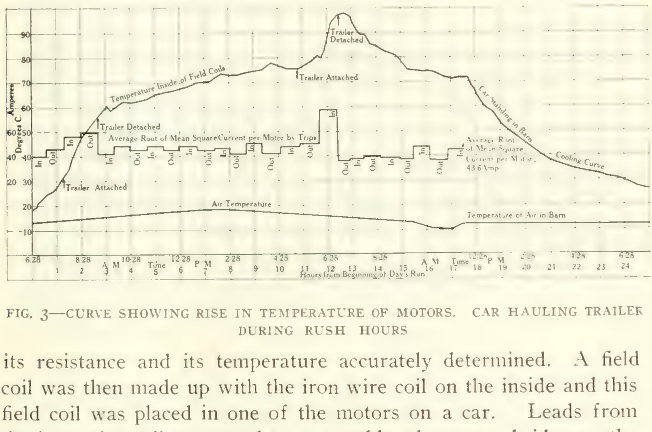


FIG. 3—CURVE SHOWING RISE IN TEMPERATURE OF MOTORS. CAR HAULING TRAILER DURING RUSH HOURS

its resistance and its temperature accurately determined. A field coil was then made up with the iron wire coil on the inside and this field coil was placed in one of the motors on a car. Leads from the iron wire coil connected to a portable wheatstone bridge on the car platform gave a ready means of measuring the temperature of the motor. Measurements could be made at any time, without regard to whether the motors were running or standing still or whether the car was using power or coasting.

The car was put in regular service on several successive days

*The results of these tests were included in a paper before the American Institute of Electrical Engineers, reported in Vol. XXII, Page 279. They were also referred to briefly in a paper prepared for the Committee on Equipment of the American Electric Railway Association in 1909. The data are so relevant to the present discussion, however, that the writer trusts he will be pardoned for repeating them here.

First, on a route where the cars were operated alone, and later on another route where a trailer was attached to each car during the morning and evening rush. By means of the arrangement described above, temperature readings were taken every five or ten minutes, not only during the day when the car was in operation, but also at night when the car was in the barn and the motors were cooling. In addition to the temperature measurements, other readings were taken, from which the root mean square current in the motors, which determines the heating, could be found. The curves in Fig. 2 shows the results obtained in a test with the motor car only. Those in Fig. 3 show the corresponding results where a trailer was hauled for the two trips noted.

It will be seen from Fig. 2, that the temperature of the motors at the start was about 25 degrees, on account of their not having

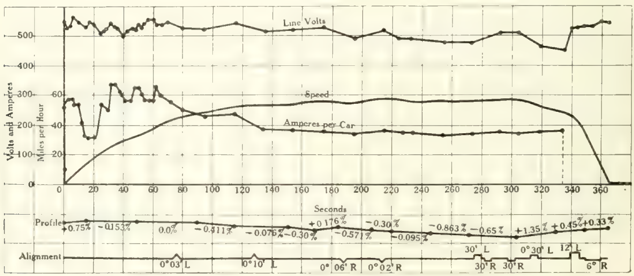
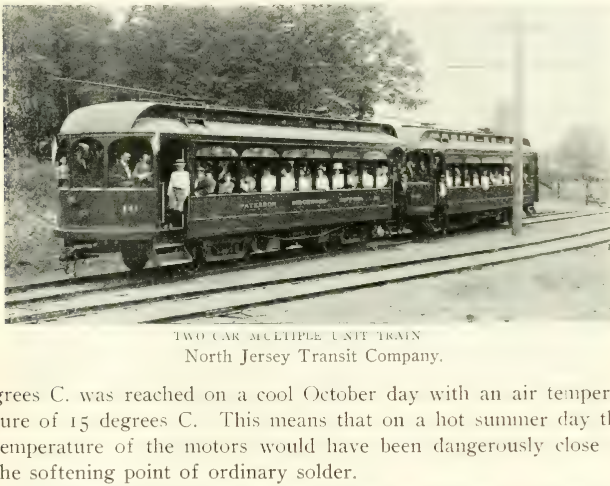


FIG. 4—CURVES SHOWING SMALL CURRENT REQUIRED FOR HIGH SPEED INTERURBAN CAR WHEN CAREFULLY HANDLED

had time to cool off thoroughly from their service of the day before. During the first eight hours, the temperature rose gradually until it reached a value of approximately 75 degrees C. at which it remained practically constant until the car was turned in for the night. It will be seen also, that with the exception of a regular difference between the outbound and inbound trips, due to the lay of the land, the loads of the motors as shown by the root mean square current were remarkably uniform.

Referring now to Fig. 3, we find that the addition of the trailer for the one trip in the morning, when the motors were fairly cool, merely caused the temperature to rise somewhat more rapidly than in Fig. 2, without causing it to reach any higher value. But in the afternoon, when the motors had reached the constant temperature at which they would otherwise have remained, the addition of

the trailer for the short space of about an hour and three-quarters raised the temperature from approximately 75 degrees to practically 100 degrees. Most of this increase took place on the heavy outbound trip during the latter half of the time A motor, having once reached a high temperature, retains its heat for a long time, and even with the trailer removed and the motors working again at their normal loads, a period of approximately two and one-half hours was required for the motors to cool down again to their normal running temperature of 75 degrees C. Had the trailer been retained for another round trip, it is evident that a much higher temperature would have been reached and a much longer period required to cool again. Even as it was, a temperature of practically 100 de-



TWO CAR MULTIPLE UNIT TRAIN
North Jersey Transit Company.

grees C. was reached on a cool October day with an air temperature of 15 degrees C. This means that on a hot summer day the temperature of the motors would have been dangerously close to the softening point of ordinary solder.

The variation in the loads on the motors with and without the trailer are shown by the curve of root mean square current. It should be noted that the load on the motors for the two inbound trips with the trailer was approximately 15 and 5 percent, and that for the two outbound trips 18 and 50 percent, greater respectively than the greatest load on any trip in the same direction with the motor car only.

In addition to its effect on the motor equipments, the use of trailers for rush hour service has several disadvantages from a

transportation department standpoint. The most important of these is the matter of speed. Handicapped already in making time and maintaining the schedule, on account of the greater number of stops which usually must be made, the heavy trips, where trailers are employed, are delayed still further by the reduction in speed, due to the added weight. The inability of a trailer to move by itself also causes delays in picking it up, dropping it, and in shifting or running around it at stub end terminals.

Although their use for local traffic is attended by the various disadvantages noted above, trailers may be employed, with very

TWO CAR MULTIPLE UNIT TRAIN
Fairmount & Clarksburg Railway.

good results, for certain other classes of service. It has already been pointed out from Fig. 3 that although the addition of the trailer for the morning trip when the motors were fairly cool, caused the temperature to rise more rapidly, than it would otherwise have done, the value actually reached was not abnormal. From the general shape of the curve, moreover, it is evident that the trailer might even have been retained for a second round trip, without causing the motors to exceed their ordinary normal maximum of 75 degrees C. and, had the trailer been attached when the car first left the barn in the morning, it might easily have been hauled for three round trips, without causing as high a temperature as by haul-

ing it for only one round trip after the motors had become warm. Thus, by taking advantage of the thermal capacity of the motors, attaching trailers only to motor cars which have been out of service for five or six hours, and leaving them attached for only a limited number of trips, extra capacity for special occasions can sometimes be obtained, without overheating the motors. In certain classes of service also, the extra load which would ordinarily be imposed on the motors by the addition of a trailer, can be compensated for by a reduction in the number of stops.

In the electrification of a branch line of a certain steam railroad, the equipment was designed with the idea that as a rule motor cars only would be used. These were intended to make flag stops

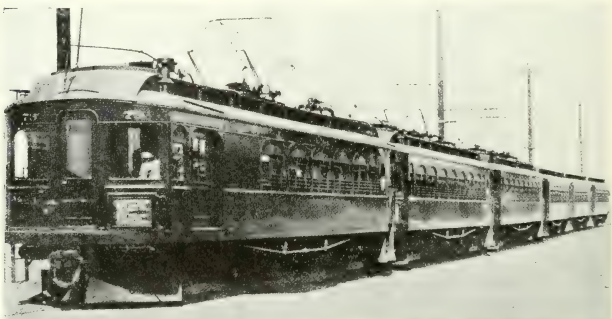
THREE CAR MULTIPLE TRAIN WITH TWO SINGLE-PHASE MOTOR CARS
Baltimore & Annapolis Short Line.

about one mile apart. It was realized, however, that on certain special trips extra crowds would have to be handled. It was planned on such occasions to have each motor car haul a trailer, but when doing this to have it stop only at the original steam railroad stations, which averaged about 2.25 miles apart. By this reduction in the number of stops, the motor cars were able to haul the trailers for any desired number of trips, to make the same schedule speed as when running alone, to impose less load on the motors, and still to have even more margin for making up time.

The many improvements in motors and control during the last few years have an important bearing on trailer operation. Interpole motors should not be deliberately overloaded any more than

the older types, but their superior commutating ability and the heat proof character of their insulation enables greater advantage to be taken of their thermal capacity than was ever before possible. So, too, the use of hand-operated unit switch control permits this to be done safely, and the full power of the motors to be utilized without the risk of "blowing up" the controllers. Even with trailers at their best, however, the multiple-unit train offers many advantages.

Since both cars are able to move independently, the making up or separating of trains can be done with a minimum of shifting. At stub end terminals there is no need for any change in the relation of the cars, for either may be used as the leading car. If the motors have been properly applied in the beginning, no question of overloading them need be considered in making up trains, since the



SIX CAR MULTIPLE UNIT TRAIN WITH THREE SINGLE-PHASE MOTOR CARS
Chicago, Lake Short & South Bend Railway.

weight handled per motor remains constant, regardless of the number of cars. On account of this uniform loading, motors can be applied to the cars more efficiently, both as to size and gear ratio, than if trailer operation had to be provided for, and smaller motors, geared for lower speed, can be used for a given car, and a given schedule. All cars can be alike, so that a less number of spares will give equal margin for emergencies. On accemt of the ease with which two-car trains can be made up when necessary, smaller cars can be employed and cheaper operation thus secured.

In view of these and many other advantages, for handling varying crowds and still maintaining a close schedule, the employment of trailers, even under favorable circumstances, seems a mere makeshift when compared to the use of the multiple-unit trains.

BRAKING ELECTRICALLY PROPELLED VEHICLES

W. V. TURNER

Chief Engineer, Westinghouse Air Brake Company

BOTH necessity and economy led to the adoption of some form of power brake for power propelled vehicles. Necessity, because to stop short under certain contingencies is imperaative, and economy, because to save time in making a stop is to make possible the earning of more money, and also, because to remove the wear of brake shoes occasioned by the motorman keeping the hand brake taut and to prevent the extra power consumption required by the dragging brake shoes, is to save money. The two together total a very large amount. One of our best known consulting engineers, who has made exhaustive investigations, informed me recently that he would be entirely satisfied with an income equal to what he could save from these two causes on one railway in New York City.

The power brake which, so far, has been the most practicable and efficient is the one actuated by compressed air, the fluid pressure being transformed into a mechanical force through a brake cylinder, piston, levers, and rods to brake shoes which eventually dissipate the energy stored in the moving vehicles, and bring them to a standstill. Where grades are concerned, the retarding force developed prevents the accumulation of energy due to gravity, and controls the vehicle to the desired or safe speed limit.

STRAIGHT AIR BRAKES

The relative merits of a purely straight air type of brake as contrasted with the automatic principles of operation may be dismissed in a word by the statement that outside of the item of expense any brake not embodying the automatic principles is not worthy of serious consideration. We are dealing with the question as engineers, not as financiers. Hence we may pass directly to the consideration of the simplest form of power brake comprising an adequate automatic protection against a loss of the brake from causes unknown to the man running the car.

STRAIGHT AIR BRAKE WITH AUTOMATIC EMERGENCY FEATURES

The straight air brake with automatic features is designed to meet the requirements of a strictly city or interurban service where

the speeds are moderate, the stops frequent and the conditions require single car operation normally and trailer services of two-car trains intermittently. For such operation, certain features of the straight air form of brake control possess distinct advantages, chief among which are simplicity of construction and ease of manipulation.

For single car operation only, it is often stated that the simplest form of straight air brake is the most satisfactory. But conditions often arise, especially where two or more cars are run together as a train, when it becomes necessary to provide some protection in the brake apparatus itself, whereby in case of a burst hose or ruptured pipe the brakes will be applied and caused to remain applied, instead of permitting the entire loss of braking power on the vehicle, as would be the result in such a case with a straight air brake only. This protection may be secured without dispensing with any of the advantageous features of straight air operation by the use of the emergency valve in connection with a brake pipe or emergency line in which pressure is normally maintained. This valve is inoperative during ordinary straight air service operation, which is secured by means of the brake valve in the usual way, and differs in no essential features from the service operation of any ordinary straight air system. But in the case of the bursting of the air hose or piping, or an emergency application made by the motorman, the sudden reduction of pressure in the brake pipe or emergency line thus brought about causes the emergency valve to operate in a manner similar to a triple valve, viz., the exhaust from the brake cylinder to the atmosphere is automatically closed, and the communication from the air storage reservoirs to the brake cylinder is opened, thus applying the brakes with full power and holding them applied.

The highest form of the semi-automatic brake equipments is differentiated from the others in that it provides for uniform pump labor when two motor cars are coupled together, since the air used in the brake cylinders is drawn directly from the reservoirs of the car to which it is attached, the brake is released directly on its own car, the brake cylinder pressure is maintained against leakage and, most important, a higher braking power is obtained in emergency than can be obtained in service, thus making it possible for the motorman to stop his car quicker than originally intended if an emergency should arise. This, it will be seen, increases the safety factor in no small degree.

The experience of some six or eight years, together with the above statement of facts, constitutes at once the recognition and proof of the sweeping statement made at the beginning of this paper. But, as hinted before, the limits of the straight air method of applying and releasing the brakes are exceeded when more than two cars come to be hauled in the same train. Following the same process of development as in steam railroad brakes, it soon became recognized that for trains of more than two cars, prompt and uniform service application and release action could be secured only by the use of a triple valve; that is to say, of the automatic principles in service as well as emergency operations.

AUTOMATIC AIR BRAKE EQUIPMENT

This equipment is designed to meet the requirements of a high class, interurban service where trains of from one to five cars are operated in towns at slow speeds and with frequent stops, but are subject to high speeds and more or less long distance runs outside these centers. For such a service, an automatic brake system is essential in order to insure the proper operation of the brakes in service, and to secure the necessary protection in cases of emergency, damage to piping system, brake-in-twos and the like. These conditions require a triple valve on each car of the "plain" type; that is, one which will operate in response to variations in brake pipe pressure, and shall have no quick action feature. The latter is not only unnecessary on account of the short length of train but would do more harm than good when attempting to handle single or two-car trains.

In addition to these two essential requirements, provision should be made for a quick recharging of the auxiliary reservoirs when a release is made in order to insure prompt and certain response of the brakes to reduction in brake pipe pressure whenever circumstances may require rapid successive brake applications; for a quick action of the brakes from car to car in service to produce rapid and definite application of all the brakes in the train; for a graduated release as well as graduated applications of the brakes in order that the motorman may control his train smoothly and accurately and in the most efficient way; and for a quickly obtained emergency brake materially higher than the maximum possible in a full service application so that a powerful reserve braking power may be available when the shortest possible stop becomes imperative.

In a common form of installation, two pipe lines are used, extending throughout the length of the train. One, the brake pipe, corresponds to the single pipe of the old standard automatic brake system, as used in steam road service. By means of this brake pipe, the motorman is able to apply and release the brakes and recharge the auxiliary reservoirs. The other, the control pipe, serves to connect the main reservoirs through the feed valve on each car from one end of the train to the other to the brake valve. It also supplies air to the triple valve on each car to assist in obtaining a graduated release of the brakes, a quick recharging of the auxiliary reservoirs, and a high brake cylinder pressure in emergency applications. The control pipe also provides a means for drawing equally upon the different air compressors so as to prevent the detrimental over-working of any one compressor.

On other installations the control pipe is replaced by a main reservoir pipe conveying main reservoir pressure from car to car to a single feed valve supplying the operating brake valve. Additional or supplementary reservoirs are then provided on each car to afford the reserve supply of air required for graduating the release, quickly recharging the auxiliary reservoirs and obtaining a high brake cylinder pressure in emergency applications. The overworking of one or more of the air compressors in the train at the expense of the others is prevented by the governor synchronizing system, to be described further on.

There still remains, where single car service is more or less frequent, the fact that:—(1) with only one brake equipment on a car, the failure of any part of that apparatus may cause inconvenience and delay or render it impossible to operate the car over the road, no matter whether the car is equipped with the straight air or automatic brake, and (2) the automatic brake on a single car requires more skill, experience and judgment for smooth and accurate handling than does the straight air brake.

There was a time when both these considerations, while recognized, had to be overlooked and allowed to work themselves out on the road as best they might on account of the ruling consideration of speed and the necessity for hauling the same car, sometimes alone, sometimes in trains up to four or five cars in length. There also come times when the human factor in the equation preponderates over the most carefully designed apparatus. All of these considerations led to the development of an equipment which should

combine all the advantageous features of the automatic and of the straight air types of brakes without their hitherto objectionable features

THE COMBINED AUTOMATIC AND STRAIGHT AIR TRACTION BRAKE EQUIPMENT

The combined automatic and straight air form of traction brake equipment has now been in service more than three years with increasingly satisfactory results. While primarily intended for service where cars are operated singly most of the time, with occasional two or three car trains, this equipment is equally adaptable to trains of any number of cars. It is especially adaptable to service such as is required of light electric locomotives, or motor cars, used for handling freight cars, switching, etc., as the facilities for quick and flexible operation of the brakes by straight air and the ease of immediately changing to automatic operation when coupled to cars, are not to be found in any other form of equipment.

Briefly stated, the advantageous features afforded by this equipment are:—

1—Flexibility and promptness of a straight air operation providing a brake easy to manipulate, quick and uniform in response, thereby saving much time in making stops.

2—All the features of straight air and, in addition, an automatic brake for safety.

3—Both straight air and automatic operations by movement of one brake valve handle.

4—Both straight air and automatic operation without interference with or sacrificing any of the normal functions of either.

5—A "straight-air-in-emergency" feature through the brake valve to brake cylinder, thus insuring a maximum and maintained brake pressure at the time most needed, regardless of the condition of the triple valve.

6—Especially adapted to cars used in switching service or for occasionally handling freight or other cars equipped with automatic brakes.

7—Both brakes must fail before the brake is lost.

It will be observed that the factor of safety in train operation is very greatly increased when using an equipment of this type, since it is quite improbable that both the automatic and straight air sides of the equipment should become inoperative at the same time.

QUICK ACTION AUTOMATIC AIR BRAKE EQUIPMENT

The types of brakes described thus far are capable of satisfying all the conditions of operation in the ordinary city, suburban, or interurban electric roads. The elevated and subway service of

large cities, however, introduces requirements of an entirely different and still more exacting character. These may be classified, according to their origin, as arising from a constantly increasing insistence upon higher scheduled speeds; longer trains; shorter and quicker stops; smoother and more accurate stops; highest possible protection against delays to traffic, and the commendable desire to utilize every possible means of increasing the earnings, of which high grade brake equipment is one of the chief requirements.

It follows from the above that to the operative features of the equipments previously mentioned there must be added:—1—the ability to transmit quick action rapidly through the train in emergency application; 2—the obtaining of as high a brake cylinder pressure in emergency as the equipment can be designed to give and, 3—the obtaining of the quick action application of the brakes with maximum cylinder pressure at whatever time occasion for the same may arise, without regard to previous manipulation, and also when the brake pipe pressure has been depleted for any reason beyond a predetermined danger point. The addition of these features makes it still more necessary to keep the margin between full service and emergency braking power as wide as possible, thus protecting the brake against emergency action when the brake pipe reduction is continued beyond that necessary for full service application of the brakes unless such over-reduction is carried below the danger point.

The triple valve used with this equipment is of the "pipeless" type. That is, all pipe connections are made permanently to the cylinder head of the brake to which the triple valve is bolted, thus requiring only the loosening of four or five bolts in removing and replacing the triple valves. In addition to the ordinary functions of all quick action triple valves, this valve includes the following improved features of operation.

1—Quick service.
2—Quick recharge of auxiliary reservoir.
3—Graduated release of the brakes.
4—Predetermined and fixed margin between full service and quick action.
5—High brake cylinder pressure.
6—Ability to obtain emergency cylinder pressure and quick action at any time, regardless of previous manipulation.
7—Automatic quick action and emergency pressure below a predetermined danger point.

A safety valve on the triple valve serves to prevent the obtaining of undesirably high brake cylinder pressure during ordinary

service operations where high speed brake pressure is carried. When an emergency application of the brake is made, however, this safety valve is automatically cut out and the high pressure obtained in emergency is held without being reduced, thus affording a maximum retarding power throughout the entire stop. Either a control line or supplementary reservoir, as explained above, may be used in addition to the usual auxiliary reservoir for the purpose of securing a graduated release of the brakes, to assist in recharging the system and to secure high cylinder pressure in emergency applications.

This equipment is the highest development of the purely pneumatic brake and possesses, to as high a degree as is possible with such a system, those features of safety and economy so necessary to the successful operation of modern electric train service. One further step and the highest development in the art of train brake control is reached.

THE ELECTRO-PNEUMATIC BRAKE EQUIPMENT

For the handling of a large amount of traffic in the most expeditious, economical and safe manner possible, the electro-pneumatic system possesses superior advantages which make it as nearly an ideal system as has yet been evolved. Since all the improvements have been accomplished by the addition of electric control to the service and emergency functions of the quick action automatic brake, it follows that the capabilities of the brake as a dividend earning investment are thereby still further extended.

The curves in Figs. 1 to 5 illustrate graphically what is meant. These curves represent comparative service and emergency stops made from a speed of 40 miles per hour, with a ten-car train equipped with the electro-pneumatic brake and an eight-car train equipped with the old style quick action brake. Curves *I* and *II* in each case, illustrate the relative drop in speed as the stopping point is being reached. Curves *III* and *IV* show the relative percentage of braking power developed.

Service Stops—Fig. 1 shows that at the time the ten-car train equipped with the electro-pneumatic brakes has stopped, the eight-car train equipped with the old style quick action brake is still moving at a speed of 25 miles per hour. This is 62.5 percent of its initial speed, and about 39 percent of the energy originally stored in the train at 40 miles per hour still remains to be overcome before it can be brought to a standstill.

Fig. 2 represents the completion of the stop in each case. With the electro-pneumatic brake, a graduated release was made so as to prevent the retardation becoming excessive toward the end of the stop. The same thing was tried on a train equipped with the high speed brake but could be only partially accomplished by making a release first and then a re-application. The great difference in rate of obtaining braking power is strongly contrasted by curves *III* and *IV* of this chart. These curves are plotted on a time base to give a more direct representation of the time saved and economic factor of the electro-pneumatic brake equipment as compared with the old standard quick action brake. It will be seen that with

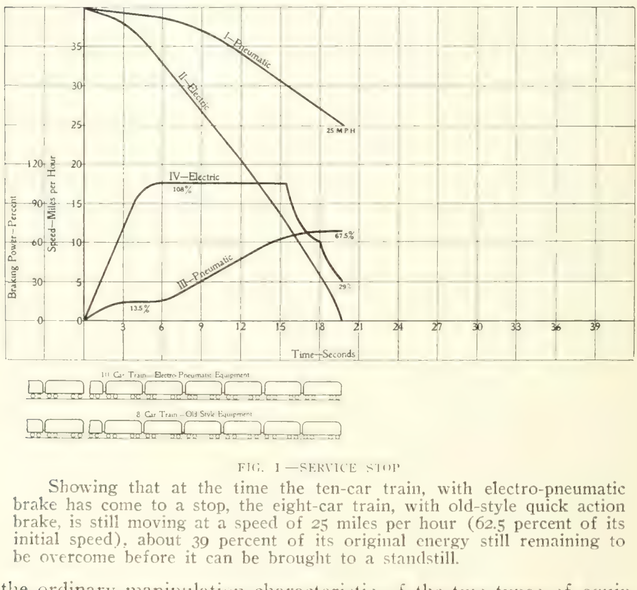


FIG. 1—SERVICE STOP

Showing that at the time the ten-car train, with electro-pneumatic brake has come to a stop, the eight-car train, with old-style quick action brake, is still moving at a speed of 25 miles per hour (62.5 percent of its initial speed), about 39 percent of its original energy still remaining to be overcome before it can be brought to a standstill.

the ordinary manipulation characteristic of the two types of equipments there is a saving of 20 seconds in time in favor of the electro-pneumatic equipment. This shortening in the time of stop means that power may be shut off sooner and the train allowed to drift for a considerably longer time before applying the brakes and making the stop at the same point. In the case illustrated, this additional drifting time was about 11 seconds.

For the same power consumption, the electro-pneumatic brake makes it possible to maintain higher average speeds, shorter schedules and an increased traffic capacity with the same number of cars or the same traffic capacity with fewer cars, or enables the same average speeds, schedules and capacity of road to be maintained as with a purely pneumatic brake but at the expenditure of less power.

Emergency Stops—Figs. 3, 4, and 5 show similar curves for comparative emergency stops with the two equipments. Fig. 3 represents the electro-pneumatic train stopped at the 350 foot mark (within two-thirds of its own length) and the old style quick

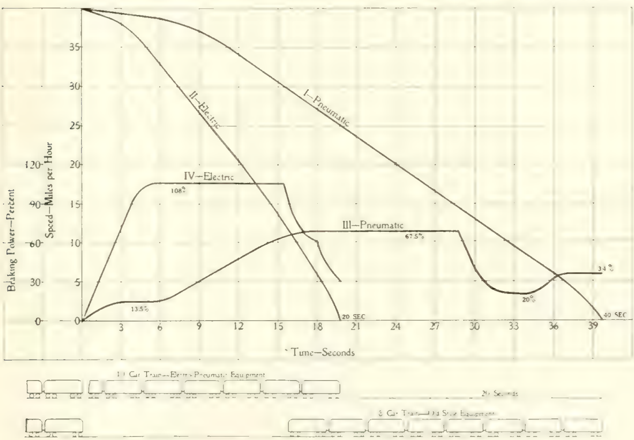


FIG. 2—SERVICE STOP

Representing comparative stops from a speed of 40 miles per hour made with a typical service application of the brakes in each case. These curves are plotted on a *time base* to permit of more directly representing the *time saved* and *economy* factor of the electro-pneumatic equipment as compared with the old standard quick action brake. With the ordinary, average manipulation characteristic of the two types of equipment, there is a saving of 20 *seconds* in time of stop in favor of the electro-pneumatic equipment.

action train passing it at a speed of 28.3 miles per hour. This is 71 percent of its original speed and corresponds to 50 percent of the energy originally stored up in the train, which still remains to be overcome before the train can finally come to rest. It will

further be noted that the train equipped with the old style quick action brakes, reaches the 350 foot mark four seconds before the electro-pneumatic train comes to a standstill at this same point.

Fig. 4 represents the status of affairs a little further along. From this chart it will be seen that at the time the electro-pneumatic equipment train comes to a standstill, the old style quick action train has run 140 feet farther and is still moving at a speed of 20.2 miles per hour, representing 25.5 percent original energy.

Fig. 5 represents a complete stop with both equipments. These curves are plotted on a distance basis to compare the length of stop and relative speed factor of the equipments. It

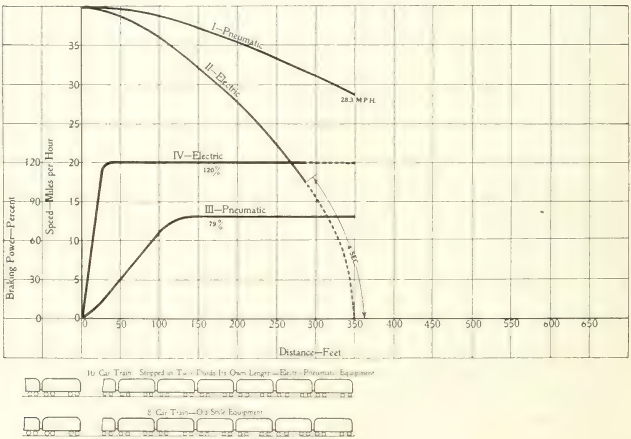


FIG. 3—EMERGENCY STOP

Representing the electro-pneumatic train stopped at the 350-foot mark (within two-thirds of its own length), and the old-style quick action train passing it at a speed of 28.3 miles per hour (71 percent of its initial speed), at which point 50 percent of its original energy still remains to be overcome before the train comes to a standstill. It will be noted that curve I reaches the 350 foot mark four seconds before curve II reaches the same point.

will be seen that the stop with a ten-car train, electro-pneumatic brake, is made in 300 feet less distance than with the eight-car train, having the old style quick action brake.

The electro-pneumatic brake system adds to the pneumatically operated brake of the highest type, certain advantageous features

otherwise impossible of attainment, namely: simultaneous and uniform response of all the brakes in the train, which means the ability to obtain perfect results with the least skill and experience, regardless of the length of train; double protection against delays to traffic, due to brake failure, since the pneumatic brake is always in reserve ready for use, if required; maximum efficiency and safety due to simultaneous operation of all the brakes in the train, in both service and emergency application and a perfect flexibility of manipulation; economy in air consumption, and maintainance of brake cylinder pressure at will.

Briefly stated, this equipment consists of a quick action, quick

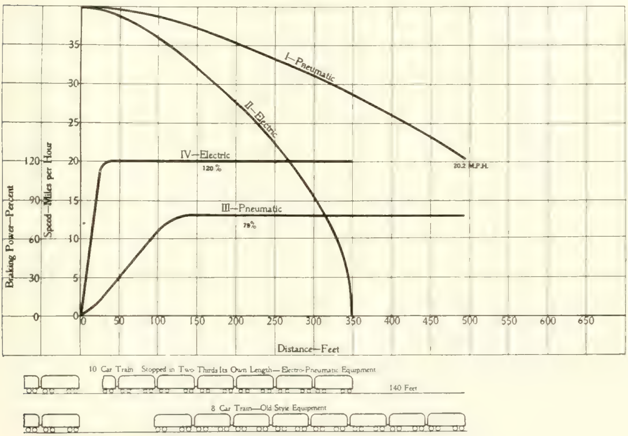


FIG. 4—EMERGENCY STOP

Showing that at the *time* the electro-pneumatic equipment train comes to a standstill, the old-style quick-action train has run 140 feet farther and is still moving at a speed of 20.2 miles per hour, representing 25.5 percent of its original energy.

re-charge, quick service graduated release automatic air brake with 30 percent higher pressure in emergency application, combined with electrically controlled means of simultaneously admitting air directly to or releasing it directly from the brake cylinders without any movement of the triple valves. Means have also been provided whereby an absolutely simultaneous movement of the triple valves of the train to emergency position is obtained by the use of electricity.

In view of the unique position occupied by the electro-pneumatic brake equipment as an ideal system capable of extension and adaptation to almost any kind of service, whether on electric traction or steam railroad lines, it may not be amiss to describe the general characteristic features and methods of accomplishing the desired results as already outlined. Compressed air is supplied to the brake system through the brake valve, at the operating end of the train, from the main reservoir pipe which extends throughout the length of the train. All of the reservoirs are directly connected to the main reservoir pipe.

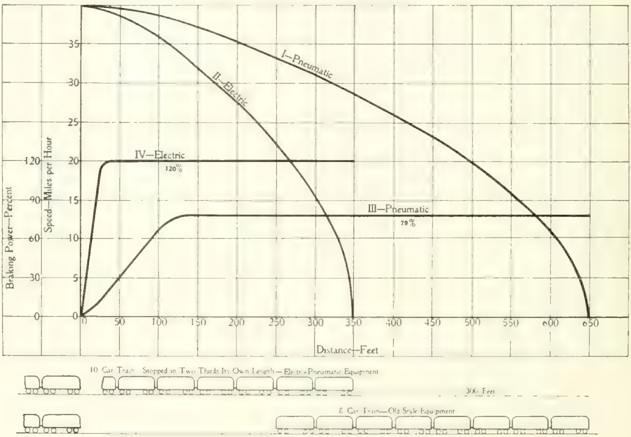


FIG. 5—EMERGENCY STOP

Representing comparative stops from a speed of 40 miles per hour with an emergency application of the brake. These curves are plotted on a *distance* base to compare the *length of stop* and *relative safety* factor of the two equipments. The stop with the *ten-car* train, with electro-pneumatic brake, is made in 300 feet shorter distance than with the *eight-car* train with old-style quick-action brake.

Pneumatic Control of Automatic Brakes—The automatic brake valve, in so far as its pneumatic operations are concerned, is quite similar to the brake valves used at present with standard pneumatic equipments. The full release position is done away with and the motorman is thereby prevented from willfully or carelessly overcharging the brake pipe in order to insure prompt and sensitive action on the part of the brake apparatus where brake applications

are required in quick succession. The upper portion of the brake valve contains an electric switch portion, controlling the operation of the electric portion of the brake system. The feed valve attached to the base of the brake valve is adjusted to maintain the brake pipe pressure at 70 pounds per square inch while the brakes are not being operated. The quick action portion of the triple valve is replaced by a somewhat similar combination of parts designed to vent air from the reserve supply carried for this purpose in the supplementary reservoir directly into the brake cylinder, when the brake parts are moved to their emergency position. This produces a very quick rise in brake cylinder pressure. Provision is made for the quick recharge of both supplementary and auxiliary reservoirs to permit of quickly replacing any air used in pneumatic application.

Since the quick action feature of the brake is separate from the triple valve and since the supply of air for obtaining high emergency pressure is separate from that used during ordinary service manipulations of the brake, it follows that both the propagation of quick action through the train and high emergency pressure can be obtained without regard to what electric or pneumatic manipulation has previously been made. The quick action feature of this equipment is contained in a device which is separate from the triple valve and connected to the brake pipe. It consists essentially of a duplex piston with valve attached and a small reservoir and chamber suitably proportioned so that when the parts are in their normal position, with reservoir and chamber charged, the pressure in the reservoir will fall with that of the brake pipe, so long as the rate of fall in brake pipe pressure does not exceed that required for the service application of the brakes. When the rate of brake pipe reduction exceeds that of the ordinary service application, the fall of brake pipe pressure and that in the upper chamber of the device is then more rapid than that at which the lower chamber can reduce. The difference of pressure thus set upon the two sides of the duplex piston causes it to move over into a position which opens direct communication from the brake pipe to the atmosphere. This causes a local vent of air with great rapidity. Provision is made in the device to close the vent to the atmosphere after the quick action has taken place, so as not to prevent the recharging of the brake pipe and release of the brakes following a quick action application. The great advantage of this vent valve for propagating quick action, as compared with a similar action of the triple valve, lies in the fact

that the service and quick action (emergency) operations of the brake system are entirely separate and independent. This practically eliminates the possibility of obtaining undesired quick action, which is difficult to prevent with any degree of certainty where the service and the quick action operations of the apparatus are controlled from the same piston and slide valve.

In whatever way a rapid fall of brake pipe pressure is produced, be it by movement of the brake valve, the operation of trip cocks or the conductor's valve, the piston in the vent valve will instantly vent air from the brake pipe to the atmosphere through a very large opening and positively insures the propagation of quick action throughout the train, however long it may be.

The only feature of the old brake equipment which has been sacrificed in this arrangement, which admits of propagating quick action throughout the train irrespective of the pressure in the brake cylinder, is the venting of brake pipe pressure into the brake cylinders. It will be appreciated, however, that with the large sizes of brake cylinders employed, i. e., 12 and 14 inches, the gain in cylinder pressure over that of service application by venting the brake pipe in this way is very small, and this is much more than compensated for by venting the air in the supplementary reservoir into the brake cylinder in emergency application whereby a brake cylinder pressure within four or five pounds of the brake pipe pressure carried can be obtained.

Electric Control of Brakes—For the operation of this portion of the electro-pneumatic brake system the source of current may be from trolley or from a battery or other source of supply local to each car. The contacts in the electric portion of the brake valve already referred to are in reality nothing more than small controller points or switches, controlling the circuits to magnets governing the service application and release and emergency portion of the brakes. With the pneumatic portion of the brake in normal or running position, the electric control of the brakes is accomplished by the aid of two magnets with poppet valves attached, governing the flow of air into and out of the brake cylinder direct or through the release port of the triple valve according to the conditions of installation.

The release magnet may be designed so that the release port is open only when the magnet is energized, or so that current is required in order to close the release magnet. Which method is

to be preferred can only be determined by a study of the operating conditions. In either case, while running over the road the exhaust magnet is holding the release valve open so that the brake cylinder is in direct communication with the atmosphere. In making a service application of the brakes the exhaust valve is closed and the application magnet is energized to open the application valve. The flow of air from the source of supply to the brake cylinder is controlled primarily by a relay valve of ample capacity, which, in turn, is caused to operate by the action of the application magnet valve. This does away with the necessity for the very powerful magnet which would be required to operate a large enough valve to supply air to the larger sizes of brake cylinders at a sufficiently rapid rate to give satisfactory service operation.

The relay valve referred to is acted upon by a spring so that when the brake cylinder pressure has been built up to within 20 pounds of that in the auxiliary reservoir it automatically closes. This valve, therefore, limits the pressure obtainable in electric service application to approximately 20 pounds below the normal brake pipe pressure, thereby incurring the valuable feature of increased braking power in emergency applications over and above that obtainable in full service applications and this without the aid of any additional device, such as a safety valve. After being raised to any amount up to the maximum contemplated in the design, the brake cylinder pressure can be maintained as long as desired by moving the brake valve handle back to electric lap position, which leaves the release magnet undisturbed but de-energizes the application magnet, allowing it to close and prevent further flow of air into the brake cylinder. A further application of the brake or a release can then be made by moving the brake valve handle either to electric application or to release position, which either causes more air to flow to the brake cylinder, as described above, or operates the release magnet valve so as to permit the air in the brake cylinder to escape to the atmosphere. If when making a release, the brake valve handle is returned from release to electric lap position, the release magnet will again be actuated so as to close the brake cylinder exhaust. In this way the brakes can be graduated off in any desired number of steps or graduations.

During the electric operation of the brake, the feed port of the brake valve is open and the communication between feed valve and brake valve is maintained. Consequently, the air which is

drawn from the auxiliary reservoir for use in the brake cylinders is continuously replaced from the brake pipe, which is in turn kept fully recharged through the feed valve. Should the motorman thoughtlessly continue the movement of the brake valve handle beyond electric application position, the brakes will continue to apply up to their predetermined maximum pressure until the handle is moved so far that a pneumatic application is begun. That is to say, the motorman cannot go beyond the point at which an electric application will cease to be made until after he has come into a position in which a pneumatic application is commenced. There is thus no possibility of a careless motorman failing to obtain an application of the brakes or losing an application already obtained electrically on account of moving the brake valve handle too far.

Electric Emergency Applications—Conditions on the New York Interborough (Subway Division) and elsewhere have become so severe as to warrant extension of electric control to the quick action and emergency operation of the brakes. In so doing an absolutely simultaneous and instantaneous application of the brakes is obtained throughout the train. This is accomplished by simply adding an emergency finger to the brake valve, an emergency wire running throughout the train and an emergency magnet with its valve controlling a port leading from the face of the triple valve piston direct to the atmophere. In order that an emergency application originating from the trip or conductor's valve, burst hose, etc., may be propagated electrically as well as when an emergency application is made by the motorman moving the brake valve handle, each brake pipe vent valve already referred to is provided with contacts whereby the operation of any vent valve in the train will energize the emergency magnets in the same manner as when the brake valve handle is moved to emergency position. The only advantage of the electrical transmission lies in the saving of time as compared with the pneumatic propagation of the quick action, but where time is an important factor, as in subway or elevated service this apparently slight saving of about two seconds may have an immediate and important bearing on the economic operation of the road and its total carrying capacity.

The characteristics of electric operation make it possible to obtain initial brake cylinder pressure much more promptly and

build this brake cylinder pressure up at very much faster rate than can be permitted with a purely pneumatic control. This is because the application of the brakes pneumatically must necessarily be slow enough to avoid the shocks, uneven braking, sliding of wheels, etc., that is likely to follow where any considerable difference in rate of retardation can occur in different parts of the same train. When the brakes cannot be applied simultaneously and uniformly (as is inherently impossible with a purely pneumatic control), it is necessary to slow down the time and rate of brake application so as to avoid the troubles mentioned above. When the application of the brake can be made both simultaeous in starting to apply and uniform in rate of building up brake cylinder pressures, a very much quicker rate of application can be utilized without danger of trouble from non-uniformity of retardation on different vehicles. This explains why the electric service brake can be made so much more effective than a brake controlled only pneumatically and further explains why at this point it became imperative to add increased power to the emergency portion of the pneumatic brake. This follows logically from the fact that if the pneumatic emergency brake is less powerful than the maximum possible with the electro-pneumatic service brake, the result would be a better service brake when operating the electric servic control than could be obtained in emergency pneumatic, which must necessarily be the final resort in case of unforseen failure or accidents. The degree to which this increase in emergency braking power over service braking power can be carried is now limited only by main reservoir pressure, as it is possible to obtain practically full main reservoir pressure in the brake cylinders when an emergency application is made, even though only 70 pounds brake pipe pressure is carried.

There is one other system which differs fundamentally from the one just described and, therefore, warrants a brief reference. This fundamental difference lies rather in the means adopted for combining the electric control with the pneumatic portion of the brake system than in any difference in principle or manipulation. With the system above referred to, the supply of air operating the brakes electrically is drawn from the auxiliary reservoir, the triple valve piston and parts remaining in their normal or release position. The brake pipe, and, therefore, the auxiliary reservoirs are then being constantly recharged through the feed valve during electric service operation. For certain combinations it has been

found preferable to make the application magnet vent air from the brake pipe to the brake cylinder, thus causing a brake pipe reduction and a movement of the triple valve piston and slide valve to their service positions just as would be the case with any pneumatic service brake pipe reduction. In emergency applications the air is vented from the brake pipe to the atmosphere, thus causing all the triple valve pistons to move simultaneously and instantaneously to their emergency positions. The release magnet controls the release of air from the brake cylinder in the ordinary way.

The electrically controlled brake therefore possesses superior features which are particularly noteworthy whether they are considered from the standpoint of the time saved, the increased traffic made possible, or the safety insured. At the present time, this type of equipment appears to be the acme of the braking art, but as past experience has always shown, the same time which brings about changes in operating conditions is also sure to develop new and more efficient means for meeting new requirements.

GOVERNOR SYNCHRONIZING SYSTEM FOR INSURING UNIFORM DISTRIBUTION OF PUMP LABOR

This system has been perfected during the last three years and is the most satisfactory and efficient apparatus for the purpose yet devised. Heretofore, in the operation of electric trains more or less difficulty has been experienced in securing an equitable division of work among the different motor-driven air compressors in the train. The result has been that some compressors are overworked, while others are not working up to their full capacity. Such an inequality of compressor operation naturally results in increased wear and tear on the overworked compressors as well as an actual decrease in the available air supply under certain conditions, due to the attendant loss in efficiency of compressor operation.

Briefly stated, the characteristic features of the governor synchronizing system are as follows:—The current supply to the motor of each compressor in a train is controlled by a switch operated by air pressure substantially as in the ordinary form of electro-pneumatic governor previously used. The difference is that in addition to the compressor switch, a pneumatically controlled switch called a "master governor" is used on each motor car, similar in all respects to the previously used electro-pneumatic compressor governor, except that instead of controlling the current

supplied to the compressor motors, it acts simply as a pilot or master switch to control the magnets which operate the compressor switches. The magnets of the compressor switches are connected in parallel between a wire, called the synchronizing wire which runs the entire length of the train and ground or negative battery terminal. The cutting in of any master governor connects the trolley or positive battery terminal through resistance to the synchronizing wire, which, in turn, energizes all the compressor switch magnets, thereby operating the compressor switches. All the main reservoirs in the train are connected by means of a main reservoir pipe line running the entire length of the train and connecting the pneumatic controlling portion of each master governor. With all the compressors cut out, the pressure in this line becomes equalized. As soon as this pressure is decreased to the point at which any one of the master controlling mechanisms operates, the closing of the master governor switch supplies current to the magnets of each compressor switch in the train, causing all of the compressors to operate simultaneously. Whether one or more of the master governors cut in at the same time is immaterial, since the cutting in of a single master governor is sufficient to start all the compressors. They will then continue to operate and raise the pressure in the main reservoirs on each vehicle, and in the main reservoir line throughout the train, until the controlling portion of the last master governor operates to open the circuit to the compressor switch magnets, which causes all the compressor switches to cut out. In this way all the compressors are forced to operate the same length of time and since the main reservoir pressure is equalized on all vehicles, the stronger compressors help the weaker ones, thus insuring the necessary amount of compressed air with a minimum amount of energy, time, and wear and tear on the apparatus.

CONCLUSION

The problems of retardation and the flexible control of trains must receive more and more attention from a scientific and technical standpoint in order that theory and practice may be combined to produce the best results in the shortest time. This is necessary if the brake is efficiently and satisfactorily to meet the wonderfully changed conditions which have developed since the invention of the quick action automatic brake. The exacting demands of the

present day require that advantage be taken of every opportunity offered to increase and flexibly control braking power.

Starting and stopping of trains are complementary factors in the problem of making time between stations; therefore, it is evident that the best results can only be obtained where both factors are given due consideration. In one sense, the question of stopping is the more important, as the safety of the service and the freedom from delays to a great degree depend upon it. The measure of the value of the brake is two-fold: 1—the ability to stop in the shortest possible distance when necessary; and, 2—to permit short, smooth and accurate stops being made in regular operation. Therefore, both these factors should be considered when design is under way. Unfortunately, the brake is usually looked upon as a safety device only, and it is because of the prevalence of this idea that its installation and maintenance do not receive the consideration merited. Considering the investment, there is no part of the railway equipment that will give greater material returns than the brake when properly installed, operated and maintained.

THE STEAM TURBINE FOR FUTURE WORK

ITS QUALIFICATIONS AND SPECIFICATIONS*

EDWIN D. DREYFUS

Commercial Engineer The Westinghouse Machine Co.

THROUGH the signal attainments and expansion of the past decade, the steam turbine has come to be regarded as the foremost type of prime mover in power plant practice to-day. The increasing volume of turbine work, reaching upward of twenty million horse-power in the short time elapsed since its advent, truly establishes its permanency in relation to our economic power problems. It seems, therefore, that only some marked revolution in the engineering art could subvert the supremacy of the steam turbine, and if coming events forecast their shadows, it is fitting that, for the immediate future at least, this type of engine should preferably be installed in modern stations. There may, of course, be conditions or circumstances which might preclude the steam turbine, such as availability of water power, or absence of cheap fuel delivery.

Rudimentary facts of turbine design and development deserve small space in a current turbine article, but a definition of the primal elements, determined by experience, upon which the choice of designs should be founded is quite important.

CAPACITIES

For electrical supply, the turbine has become commercially available in sizes ranging from a fraction of a kilowatt to 30 000 kilowatts in a single unit. Thus, from the diminutive locomotive head-lighter to the gigantic engine now demanded by the metropolitan service stations, all requirements within these limits for the generation of electricity from steam may be fulfilled by the turbine to the highest degree of satisfaction. This type of prime mover, free from heavy reciprocating parts, reversal shocks and vibrations, is not encumbered by the restrictions that have made its predecessor, the piston engine, unfeasible for many applications which are to-day being completely satisfied by the rotating type. It was the turbine that made it possible to develop high powers on shafts of reasonable diameters, thus providing for the designs of the large Cunard liners, Mauretania and Lusitania, and later mammoth vessels.

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*A paper read before the Indiana Electric Light Association, South Bend, Indiana, August 24, 1911.

In steam turbine work the designing engineer has fortunately been in a position to elect from two well known methods of heat energy abstraction, commonly designated as the impulse and reaction principles.* The problems of applying these principles to the greatest mechanical and economical advantage in turbine design vary according to the magnitude and importance of the service. Accordingly, turbines naturally classify themselves with regard to capacities as follows:—

Small steam turbines, under 300 kw, necessarily assume an elementary form—a simple impulse wheel—compatible, however, with the efficiencies established by good practice.

Units of moderate size from 300 to 1 500 kw or somewhat above, must possess high efficiencies, and also sustaining qualities, as the extent of operation grows in importance. These requisites naturally suggest the reaction type.

Large machines must embody the best features of the preceding class, but at the same time any involved construction, due to the magnitude of forces and proportion of parts, must be avoided and these considerations prompt the consolidation of the two principles. A noteworthy innovation in turbine design appeared several years ago in the form of an effective combination of the two types, technically termed a combined action and reaction turbine. It has, however, became most familiar to the electric power station through the characteristic double flow design, which is used in the high powered units.

VARIED APPLICATION

In view of increasing problems confronting power engineers and central station companies, it is most opportune that the steam turbine admits of an extremely wide deviation from usual working conditions. Many commodities which but a few years ago were luxuries are at present every day necessities, and thus it becomes the duty of the public service company to distribute economically to consumers *light* and *power* primarily, and also *heat* in some cases.

The diversity of service requirements has evolved several distinct constructions meeting these various operating conditions whose characteristics and uses are designated respectively, complete expansion, low pressure, non-condensing and bleeder turbines.

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*While in all practically built turbines these two principles occur conjointly in the development and absorption of velocity energy, in either case the one predominates over the other, wherefore they are ordinarily distinguished.

Complete Expansion Turbines—The complete expansion turbines essentially rank first owing to the predominance of their use. As identified by name, these turbines receive steam at the highest steam pressures and temperatures (superheat), expanding it continuously to the highest vacua. Where high boiler pressures (ordinarily above 175 lbs. gauge) are used, but a small part of the turbine is required to withstand the accompanying stresses, as high pressures are confined within small nozzle blocks. With the piston engine, on the other hand, the high pressure cylinder must safely accommodate these forces. Turbine design involves no rubbing surfaces so that lubrication under high temperatures, requiring special valve and packing design and lubricants, is no longer a factor.

The profitable use of moderately high vacua is another commendable feature of the turbine and is readily accomplished without impractical or uncommercial proportion of parts such as would become necessary with the low pressure cylinder of the piston engine for such vacua. Therefore, higher heat efficiencies obtain with the turbine, contributing, of course, toward a lower cost of production, a requisite not only from increasing competition and public demand, but also from the more ethical standpoint of conservation.

Low Pressure Turbines—Low pressure turbines at present hold a position second to that of the complete expansion type, since they are capable of receiving steam at the pressure at which a piston engine* would exhaust the steam after expanding it throughout its economical range of operation (boiler pressure to atmasphere), and completing the expansion to high vacua with the same degree of efficiency; that is, briefly stated, extracting an equal amount of effective energy from the steam, or more tersely, *doubling the output of a non-condensing reciprocating engine plant without increased coal consumption.* Considering a reconstructed condensing engine plant, the absolute improvement will usually be from 10 to 50 percent or more according to degree of economy in effect prior to including the low pressure turbine. This valuable property of the turbine is therefore vitally important to stations operating reciprocating engines, on the following counts:—

*And other sources of atmospheric steam supply.

1—Reducing operating expenses............	a—Fuels b—Oil c—Labor d—Repairs
2—Advancing the value of plant investment.	a—By re-instating the utility of the engines, thus preserving their existing rated worth b—By obtaining increased capacity at the lowest possible unit cost
3—Improving the service.	a—By simplifying operation and reducing the condensers ordinarily used; or for former non-condensing plants by providing a good source of boiler feed. b—In securing better cyclical regulation, an inherent quality of the turbine c—Placing least taxation on boiler plant through the small rise in water consumption on overloads.

Here the salient facts only, pertaining to the low pressure turbine work are enumerated. The engineering features which may surround the installation of low pressure turbines assume various forms based upon plant conditions and methods of operation, and thus introduce different provisions:—

a—Without governor—electrically controlled through synchronizing force of generators.
b—Governor control with auxiliary live steam admission.
c—Interlinking turbine and belted engines through synchronous motors.
d—Automatic by-passing of low pressure steam to condenser.
e—Use of a reserve high pressure element.
f—Heat regenerators, accumulators and storage systems.

These divisions summarize the extent of low pressure turbine engineering, and this subject in itself has hitherto proven worthy of many deliberate expositions.

Non-Condensing Turbines—Considered as a main generating unit the non-condensing turbine has correspondingly found a field of usefulness but, to a limited extent, however, as compared with the other types heretofore described.* The proper sphere for the non-condensing design is where exhaust steam is used abundantly. Where heat supply becomes an important element of public utility service or of industrial plant operation, a strictly non-condensing unit or perhaps a certain small number of such units may be recommended, providing the electrical load drops off in the warm weather months in a fair proportion to the heating demand occasioned in winter.

Some criticism may be directed against the use of large non-condensing steam turbines by those prejudiced in favor of the pis-

*Extensively used for auxiliary service, however.

ton engine. With recent advance in turbine design it is now most difficult to show cause for the reciprocating engine on the basis that it consumes less steam when operating with atmospheric exhaust or higher back pressure; in fact, any difference in service due to wear may easily fall to the credit of the turbine. Results obtained with a drum-type Parsons turbine with seven pounds back pressure compared with an engine in excellent order show a disparity of scarcely five percent at full rating. This difference vanishes on loads less than one-half of full load, the fact being borne in mind that with mal-adjustments and leakages of valves and pistons the steam engine may not be constantly maintained under these so-termed test conditions.

Moreover, a well designed turbine should not perceptibly deteriorate in operation, and impartial tests confirm this fact. But let it be remembered that there is a saving in *oil, labor,* and *investment* with the turbine, and a considerable reduction in *maintenance expense* of the *distributing mains* as a result of the entire freedom from oil, which will greatly overshadow the slightly better fuel economy of the piston engine. And, inasmuch as the exhaust is fed to heating mains, the somewhat greater consumption of the turbine may in no sense represent a disadvantage, but on the contrary may prove most advantageous.

Automatic Bleeder Turbines—Bleeder turbines owe their existence to the necessity of a mixed lighting and heating supply from a central power station. While in some plants, chiefly large ones, the complete expansion turbines and the non-condensing type may be successfully co-ordinated to produce the highest economies in all directions, both the moderate and small sized stations, with a dissimilar flunctuation of light and heat loads throughout the day, month and year, would find it virtually impossible to regulate their equipment for constantly attaining the most efficient results. It would, moreover, probably call for a greater station investment to provide adequate flexibility.

In compound condensing engine stations, it has been a very general practice in cases of this kind to draw steam from the receiver, this being practicable at all loads with engines having cut-offs on the high and low pressure cylinders operating in parallel. In early turbine designs an improved expedient was followed to a partial extent by tapping steam from a given stage in which the pressure under any reasonable load would not fall below that maintained in the heating system, thus guarding against any interfer-

ence with the supply or service. This method of operation was accompanied by two disadvantages:—First, only a *limited* low pressure *steam supply* was available through this means since, on light loads, the pressure in the turbine may fall below that in the heating system, and secondly, a pressure reducing valve was necessarily introduced between the turbine and the heating system, which produced a *loss in throttling* the steam.

Such diversified requirements in joint heat and electrical demand directed the attention of the turbine engineer to an important and increasing problem, viz., that of devising a method by which both the heating and electrical supply would be automatically and economically delivered in accordance with the demands of the respective systems. The most effective and dependable solution has been the location of a pressure controlled valve between the high and low pressure sections of the turbine, *automatically diverting to the heating system the exact amount of steam required* and at precisely the predetermined presure.

This design is commercially designated as the automatic bleeder turbine and in moderate capacities promises an interesting issue in the new era of utility service.

Through the employment of a special constant pressure valve between a system of reciprocating engines and a low pressure turbine an exactly similar function to the bleeder turbine is secured, which deserves careful thought in the extension of the older plants containing steam engines.

DIVERSIFIED SERVICE

As is well known, electric power production has created a demand for the turbine far in excess of all other stationary uses combined, and manifestly for two reasons, first, the turbine is preeminently high speed, its general adoption being realized through the successful development of high speed and direct coupled generators, and second, the significant growth of electricity as a modern convenience.

Lighting, being the greater necessity, has brought the higher frequency (60 cycle) units forward in moderate size stations. Large plants with a heavy direct-current load and rotary substations mainly employ 25 cycles. Railway and general power apparatus has therefore operated at 25 cycles, with occasional exceptions of 15 cycle or direct-current generation, it being understood that as a rule direct-current for railways is obtained through

rotary converters. The partial classification, including chiefly 60 and 25 cycle service, comes within the realm of compatible speeds of both the turbine and generator. Lower speeds necessitated by 15 cycle and direct-current work compel a compromise of the efficiency and the mechanical structure of the two elements.

Through improvements in design and manufacture, large reduction gears have become feasible for interpolating between the most desirable speeds of the turbine and generator respectively. However, direct coupled generating units of about 300 kw and under are being suitably fitted to the needs of excitation sets and similar direct-current service, where the current is small and high economy is not essential. Centrifugal boiler feed pumps for plants of about 2 000 boiler horse-power, ranging in size from 15 to 100 brake horse-power establish another class wherein direct connection of the turbine proves commercially practicable. The wisdom of immediately gearing the turbine to large direct-current generators and centrifugal pumps, screw propellers in marine practice, and other slow speed applications, has now been fairly decided by the successful large, flexible gear, giving rise to unrestricted latitude in design of the component parts with respect to each other. A single reduction gear or else a train of gears has also brought rolling mill requirements within the bounds of the steam turbine. These illustrations accentuate the diversity of uses to which the turbine may be applied; in general, therefore, it is to be reasonably inferred that this type of power unit will largely prevail in our modern institututions.

MECHANICAL CONSTRUCTION

There are, probably many engineers who are as yet not familiar with the practical fundamentals in turbine engineering, and reasonably sc since the turbine is still young and their experience pertains mainly to the piston type of engine. Obviously, the problems in the design of reciprocating engines differ widely from those in turbine design. Reversal shocks and strains and static forces make it imperative that the connecting rods, pins, crank discs and other workin parts be of very heavy construction in relation to the power transmitted. Turbines, on the other hand, absorb the energy in the steam dynamically, in many progressive steps with high "material" speed, but owing to the small masses, the unit stresses in the various parts are comparatively low, notwithstanding the greater centrifugal forces. As an illustration, the holding strength of the blades in the best Parsons designs is 40 times the forces tending to dislodge them in normal operation.

An obstacle in early turbine construction was the involved cylinder design which militated against uniformity in expansion and contraction of the parts. This was unrelentingly assailed by adversaries of the reaction type turbine and in fact was really productive of periodical blade troubles. However, the reasons for this are very plain in the study of the "old" line of turbines. While the explanation is very simple in retrospect, the turbine obviously required this ordeal in its commercial development stage to bring it to the point of success which it has now attained. These early difficulties were due principally to the equalizer ports and supports being cast integral with the cylinder in all important sizes, producing a variation in the depth of metal at different points, thus causing the cylinder to camber slightly with temperature changes. The above troubles have been eliminated in all important designs by removing these exterior parts from the cylinder casting proper. As this improved practice has now been in effect for three years in leading turbine work, there has been ample experience in the operation of a great many units of this advanced construction* to prove its unqualified merits.

There were numerous cases, in the early days, of blade mishaps from contact due to the distortion, as above noted.

However, different qualities of blades have been employed until a successful composition and quality was secured. Steel and copper clad blades which were used in certain stages of turbine history soon gave out where the steam possessed any chemical properties. However, a great many turbines so equipped have not shown any appreciable signs of blade deterioration after several years of constant operation where the boiler feed was uncontaminated. Thus, a 1 500 kw Parsons turbine with steel blades, installed in the central station at South Bend, Indiana, was recently opened after four years constant service and found to be in excellent condition. Collections of blades which suffered from the preceding causes have been circulated in certain instances as proof of inherent disability or inadequacy of the type for continued service. It is not believed that such methods can influence those looking for facts as they now obtain.

Another view point should be considered, relative to the design of blading. No mechanism of human invention is absolutely proof against all vicissitudes, and it therefore devolves upon the engineer

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*See article by the author on "Some Steam Turbine Considerations" in the JOURNAL for March and April, 1911, pp. 247 and 375.

to incorporate a link in the system which will sustain the brunt of any unfortunate happening and which may be restored with the greatest facility and the minimum cost. This recourse should be provided for in the blading element, and with such design in view it will be evident that any attempt to unduly reinforce the blade construction may defeat this purpose. Obviously localizing all possible troubles in the blading would precipitate the least consequences—often too trifling to interrupt operation.

Heavy blade and disc construction may, to the lay mind, be construed as prima facie evidence of strength and rigidity. But, when actually deviating from approved and designed conditions of operation, such features may bring about most serious results. To the discriminating engineer, it will therefore be plain that the drum type of turbine construction using low peripheral speeds and with a minimum of danger from distortion or warping, is mechanically superior. Moreover, the tremendous latent energy of high speed discs due to the depth of metal and its consequent weight deserves careful thought in connection with its bearing on the possible rupture or weakness of any section. Furthermore, no abnormal strains should be introduced in the turbine in changing from condensing to non-condensing operation and vice versa. Should the outer rim of a disc be more quickly lowered in temperature in converting to condensing service, the plate may buckle, rendering the unit not only unserviceable but unsafe.

Exterior Design—Capitalizing the outward design of a machine is permissable not only from the æsthetic standpoint but also in consideration of the psychical effect produced. Although power machinery is not sought for adornment of the property or interior but is exclusively for service, the fact remains that effective outward design conduces toward confidence in the installation and that it may frequently facilitate operation by removing from sight the ungainly parts which otherwise might obstruct the view of the attendants. All oil and water piping, the cooling system and heavy valves should be placed below the floor line when their location above the bedplate offers no advantage. Care in design begets corresponding care in operation.

ACCESSIBILITY FOR INSPECTION AND REPAIR

Every machine, if at all worthy of an important service, deserves intelligent treatment in its operation. This means that it should inherently permit of easy access to all its various parts, so

that it may be inspected periodically to determine whether it remains in normal condition or if small replacements or cleaning should be undertaken. If a large amount of dismantling is involved, the internal parts are liable to suffer neglect, either reducing the economy or causing the eventual repairs or damages to be excessive. Where these considerations are disregarded in the design, the operation of tearing down the parts, which subsequently may possibly be compulsory, proves very costly and where the inaccessibility is marked the operation of forcing off and pressing on discs, may result in augmenting expense due to ordinary operating wear.

If the feed water is chemically active, it is important that provision shall have been made for lining the cylinder to prevent wall corrosion due to organic or inorganic elements, whatever they may be.

INHERENT CHARACTERISTICS

The elementary distinction between "impulse" and "reaction" designs is that the former employ high relative velocities across the blades with equal pressure on either side of the rotating buckets, whereas in reaction blading low relative velocities obtain and a drop in pressure, or in other words expansion, also progresses in the blades, as they themselves really constitute small nozzles. The use of low velocities entails the least abrasive action of blade surfaces from steam jets, the wear probably varying approximately in proportion to the square of the relative steam speeds. The effect becomes more serious with the presence of moisture and provides a logical reason for establishing reaction blading in all low pressure stages for the larger turbine capacities, typical in Europe as well as in this country. To offset the effect of moist steam of high velocity in the impulse type, increased superheating is being recommended to delay the occurrence of saturation (i.e. the dew point), so as to limit it to the last stage, or in other terms to ensure dry steam throughout the expansion. This naturally requires more costly boiler outlay and piping systems with their attending liability of greater maintenance expense. A gain may thus be derived from the view point of repairs, but not in the sense of economy at the fuel pile. Prominent European builders of impulse turbines, in taking cognizance of these facts largely subdivide the low pressure stages to attain low steam velocities.

Since in the reaction type, the greater part of the work is performed as the steam issues from the blades, the necessity of a sharp

and well preserved entrance angle is of comparatively little moment. But in the impulse type the greater part of the dynamic energy in the steam jet is exerted on entering the buckets, so that it is very necessary that the blades and direction of the jet be correctly maintained. Thus it is manifest that the reaction turbine will show greater permanency as regards efficiency, either in case of slight wear or scale deposit in the blades.

Unequal pressure on the sides of the rotating blades in the reaction type creates an end thrust, which must be properly counterbalanced, a simple provision in medium sizes. Large capacities induced the development of the now well known double flow turbine, which not only solved the balancing problem, but enabled the use of higher rotative speeds and provided large blade areas in the final stages, both factors of economy. Although the impulse type does not ordinarily experience any unbalancing of pressures on either side of the discs, an accumulation of foreign matter upon the buckets may restrict the steam sufficiently to produce a considerable force in an axial direction, due to resulting friction and impact. Being without means for counteracting heavy unbalancing, the thrust bearing may become dangerously overloaded.

More advantages accrue from the use of a great many small blades in reaction turbines than are at first apparent. An accidental collision of the rotating and stationary elements may only result at the most in stripping a small number of blades, and under this slightly crippled condition the turbine may safely be continued in service, a practice which in the case of the disc type turbine, with its heavy blades and thin shafts, would generally be prohibitive due to the danger of vibration from an unbalanced rotor.

There is a misleading idea that one type of turbine may be designed for a greater degree of efficiency when high vacua are used, but it is a fact that no actual difference exists, as may be easily demonstrated graphically. However, the change in economy of any particular type with change in vacuum during the operation, will depend to some extent upon the number of stages or rows of blades which it contains; therefore, the turbine with the fewer rows or stages is more sensitive to changes under operating conditions and will more rapidly decline in efficiency if the auxiliary equipment is not kept up to the original standard. Besides, the amount of effort and expense which is warranteed in maintaining high vacua is plainly debatable when the greater auxiliary power and investment

are fully reckoned. In reality it is simply an economic problem which in any particular installation settles itself.

Regulation and Operating Qualities—Stability in operation is essential in all power stations, large and small. Swinging of load (or as sometimes called hunting) between various units, if not corrected, may become so aggravated as to impair or jeopardize the service rendered by the plant. While wide regulation from no load to full load is preferred in parallel operation of alternators, it does not relieve the governing mechanism from the duty of promptly responding to load changes. To effect smooth regulation and obviate tendencies to race and hunt, the "fly-ball" regulator must be sufficiently powerful to overcome without hesitancy any momentary sticking or binding as well as the inertia and friction of rest. In hydraulically operated valves, the pilot valve should be placed as close as possible to the operating cylinder, so that no lag will occur which may introduce poor regulating quality. In large stations chiefly, and other plants where the loads remain very uniform for long periods, or change gradually, these features may not assume such importance as indicated. But, allowing that the swing on the station are of an appreciable amplitude, as occurs with interurban electric railway loads and in industrial plants having rolls, bulldozers, elevators and similar intermittently operating apparatus, sensitive regulation is especially demanded where office lighting is furnished from the same source of current.

Simplicity in valve and governor mechanism is paramount to ensure instant action at any critical moment. Gradual steam admission gives a smooth regulation curve, and the governor must control but a single valve. Where each step in valve operation represents say 300 hp, the sluggish action or sticking of any one valve may prove to be enough to bring about unfortunate results. The governor or regulator should be supplied by forced lubrication and encased for safety of the operators. When in service, the turbine should require a minimum of attention under any and all variations in load. It has scored materially over the reciprocating engine in the matter of small attendance, and this possibility of the turbine should not be neglected or overlooked in power station design and supervision.

EFFICIENCIES

Scarcely any reference to the comparative economics of reciprocating engine and turbine need be made. Their relationship is already well established. In strictly condensing service the turbine

as previously noted is more efficient, with the exception perhaps of very small units. For non-condensing work the engine may show a somewhat higher heat efficiency, but often the reverse when *final* capital economy is considered. There is much to be said, however, regarding the performance characteristics of different turbines. Turbines of various builds could not be expected to coincide in the results they produce, and for important reasons, since blading formation and proportions are the governing factors. The superior efficiency of nozzles over buckets has been thoroughly settled. Hence, turbines employing the reaction principle, with the blades constituting nozzles, should surpass other types by from 5 to 15 percent, notwithstanding radial leakages. According to all records the reaction type with high pressure impulse wheel has developed the best results thus far obtained. The proper measure of turbine performance is the efficiency ratio or Rankine cycle efficiency, i. e., the ratio of equivalent energy transformed into effective work to the heat energy actually available. *Water rates alone* do not exhibit the true economy of the turbine, station equipment. These facts are of more than technical interest and bear critical study. Moreover, they concern the operator as well as the designer and are also important points to bear in mind in connection with the question of economy guaranteed. Power engineers in their zeal to procure unreasonable efficiency often encourage hazardous guarantees. The latter practice has not been shunned as it justly deserves, for the reason that conclusive tests are improbable in the majority of cases, yet, heretofore, the attention given the subject has been too insufficient to expose the fallacies, both in guarantees and erratic tests. Many reliable tests now on record furnish fair standards of performance under different operating conditions. Therefore it behooves those installing new turbines to specifically analyze the important features which underly this industry. Penalty and bonus stipulations are only a mask unless the approved test conditions prevail and trials are conducted conscientiously and skillfully. Nevertheless, within reasonable limits, the award and penalizing on improvement or deficiency in guarantees, on the whole, serve as an excellent method of agreement and should be adopted and carried to conclusions in every possible case.

MAXIMUM AND NORMAL RATINGS

Within the last three years, a new reference for rating generating units and other electrical power apparatus has come into

use to a limited extent. This has taken the form of basing the full-load capacity on the greatest amount of power which may be delivered by the machine continuously without dangerous heating, or strains or serious falling off in speed. The capacity, thus determined is called a *maximum rating*. Previously, the more conservative practice provided all important machinery of this class with a continuous marginal overload of 25 percent; this was distinguished as the *normal rating*. Each method of rating is to be respectively endorsed under appropriate circumstances. Only where there is definite knowledge, however, that the unit will not be compelled to operate constantly at some greater capacity than fixed upon, should maximum ratings be employed, for these remove the conservatism so essential in important service and should therefore be confined to special cases. Turbines rated on a maximum basis are incapable of carrying full load should the vacuum be accidently lost, which might embarass the operation of the plant. Boilers ordinarily possess sufficient inherent overload capacity to provide the increased steam required to run the turbine non-condensing. Moreover, the boiler plant should not be rated at its maximum output, as a higher efficiency obtains at a lower rating.

As regards the *different ratings*, the design for the normal rated turbine would not necessarily be changed to produce better light load economy, for no advantage would accrue even on fluctuating load, as may be shown. It would mean though in the maximum rated turbine that all the possible power was being forced from the same frame used for the machine when normally rated at lower capacity. The unit cost, i.e., per kilowatt, of a maximum rated turbine is necessarily lower than for the *normal rated* machine, while they may be identical in every respect. Delusions of this nature have frequently caused real misapprehension.

The power-factor of electric loads must also be considered, its neglect in many plants having resulted very unfortunately in serious overheating of the generators.

CONCLUSION

In expounding the truths as we best know them, the author offers these suggestions for the benefit of those who have been debarred through lack of time and opportunity from an intimate familiarity with these vital turbine elements, and it is hoped that, as thus correlated, the various phases of the subject that have been discussed will carry the value properly attached to them.

ELECTRIC MINE HAULAGE

DETAILS RELATING TO MAIN ENTRY WORK

G. W. HAMILTON

Engineers and salesmen are frequently hampered in making recommendations for new equipment by lack of specific information as to the conditions to be met. As it is, of course, essential that any recommendations made be on the safe side, this lack of information frequently results in the recommendation and sale of larger and consequently more costly apparatus than the conditions warrant. The following article gives an idea of the detailed information which is necessary in the application of electricity to coal mining. It is, typical of the kind of data which should be obtained before a final selection is made of apparatus in general. (Ed.)

BEFORE laying out a system of mine haulage by means of electric locomotives a thorough study of local conditions should be made in order that the output may be handled quickly and conveniently, and that the equipment be of a type and size best suited to these conditions. As the work to be done varies greatly with the system of mining and location of the mine, a typical case will be considered.

Assume that the output of a mine, together with increasing length of entries, demands greater hauling facilities than can be afforded by mules; that the mine is worked on the room and pillar system; that the mules will be retained for gathering; that the locomotives are to be used for hauling in the main entries only, and that all information necessary for selecting the locomotives, power house equipment, etc., must be secured on the ground.

As the keynote to the whole situation is increased output from an ever increasing distance from the shaft at less cost per ton, accurate knowledge of the present and prospective operating conditions should be fully discussed with the mine officials. If maps are available showing the underground workings and profile of the main entries, a record should be taken of the distances, grades, etc., in all parts of the mine where locomotives will be used.

The next consideration should be the output in cars delivered at the bottom of the shaft, not only on an average day's run, but under maximum conditions, and how many hours can be counted upon in which to collect and haul these cars. Then information should be secured as to where these cars are obtained, including not only from which cross entries they are hauled, and from which rooms on these cross entries gathered; but how many cars each room can furnish if properly tended, and the average distance from

the rooms to the main entry and the shaft. When this information is checked against the number of mules employed it gives the value of each mule in cars per day under actual conditions, and will guide in the location and length of the main parting, or sidetrack, which should be placed to give each mule as short a run as practicable, and at the same time an equal share of the total work. This parting, when located to advantage, can readily be advanced as the main entries are driven ahead and new cross entries developed.

The location and re-location of the main parting gives the length of run to be covered by the locomotive now, and in the future, as well as the frequency of service from the rooms and cross-entries by the mules, and the cars they will haul per hour or per day under working conditions. These items control also the size of the locomotives required, the cars to be hauled each trip and the frequency of the trips, because the plan should be to provide equal service for each entry and room. If a profile of the main entries is not on hand a record of the steepest grades with their location, length, direction and percentage should be made.

Another important detail to be secured is the weight of the empty cars. Several cars should be weighed in their present condition and an average taken. The load in the cars may be obtained from the mine records and, as this figure is apt to vary, an average of the heavier loads should be used. The cars should also be measured, and the length, width, height, wheel base and details of bumpers and couplings noted.

The question of voltage is generally determined by the mine officials. If those in charge have no decided preference it will pay to leave this matter unsettled until conditions below ground have been investigated.

The number and size of locomotives, together with any other equipment, will determine the generating units which will be necessary. To find out whether additional boiler capacity will be required, the number and size of boilers installed, the number in daily use, the average steam pressure given, and how much surplus capacity is available when all steam driven machinery is at work, should be ascertained. If the generators are to be placed in the hoisting engine room, the steam pressure should be measured at this point while coal is being hoisted. The distance from the boiler house, size of steam main, and kind of heat insulation will also serve as a check on the steam pressure which may be expected at the generator engine when its location has been decided upon. The capacity of

the hoisting engines in cars per day may be secured from the engineer, as well as the maximum load they can hoist and hold back. The first item controls the maximum output of the mine. The second determines whether the locomotives may be placed in service complete, or taken apart. If they must be installed in sections, the manufacturer must make suitable provision in their construction.

When the location of the generator, and its switchboard has been settled, the location of the feed and return cables should be ascertained. That is, will they be overhead or underground, and will they be placed in the main shaft or in the air shaft? The condition of the shaft, whether wet or dry, the space available, the distance from both shafts to switchboard, the depth of shaft and the path to be followed will determine both the character and the length of the cable, the number of poles, cross-arms, insulators, etc. A list of all machines which would be better served if motor driven should be included, securing details of location, horse-power, present system of operation, frequency of service, etc., and also the disposition, number and candle-power of lights desired.

On stepping from the cage at the bottom of the shaft the first point to determine will be, how far the feed cable should run before meeting the trolley wire, the conditions controlling this being the height and width of the entry and the length of the bottom. If the entry is narrow and low the trolley wire should not come near the shaft, but should be stopped far enough from the cage to be out of the cagers way; on the other hand if height and width permit, the feed and trolley wire may be connected near the bottom of the shaft, thus reducing expense. The return cable may be attached to the main tracks near the bottom of the shaft. If the feed and return cables are brought down the air shaft, the distance from air shaft to main entry should be measured and the air course between these points gone over, to determine the number and kind of insulators.

Before leaving the bottom of the shaft note the length of the tracks used for caging the loaded cars, and storing the empty cars, obtaining the maximum capacity of each in cars, and a statement as to whether they can be extended to suit haulage conditions. If the present conditions cannot be changed to suit increased capacity per trip, the number of cars per trip must be correspondingly limited.

In order to become familiar with the general conditions, a good plan is to walk slowly over the haulage entry from shaft to face noting the details which control the situation such as the location of the track in relation to the center or rib of the entry, the clearance

between near rail of track and rib of entry, or other obstruction, such as props, door posts, etc., and if this clearance be less than ample for the locomotive, whether it can be changed to suit. The gauge of track on tangents and on the curves should be measured, checking the distance in several places, and if the rail now laid weighs over 16 pounds per yard note the weight and average length of each rail. If the rail is not heavy enough to carry a main haul locomotive, a safe rule for the mine being, ten pounds per yard will carry a load of 1 500 lbs. on each wheel, the weight, length, and gauge of the new track will have to be determined when laid. The height from rail to roof, maximum and minimum, the kind of roof, and the grades, should be checked with the data obtained above ground, and the radius, length and location, of all curves of less than 50 feet radius noted, that by the time the proposed location of the main parting is reached, information governing gauge of track, weight of rails, length of rails, clearance between rail and rib, radius, length and location of curves, height and location of trolley wire, number of bonds and cross-bonds, number and kind of trolley hangers, and other trolley details will be known.

The parting should be made long enough to hold two trips, or loads of cars, at once if practicable. This plan insures steadier operation, because should any delay occur when a trip is being hauled, it will not hold up all teams and drivers inside unless the time lost be twice that required to make a round trip to and from the shaft.

The length of the run from shaft to parting and the general conditions determine the voltage to be used, it being controlled by the height of the entry, the clearance between rail and rib, the condition of the roof, whether good or poor, the condition of the entry, whether wet or dry, etc., and the safety of the men. The safety of the mules has little influence in the decision, as either 250 or 500 volts generally proves fatal to them. If the mules must pass under or near the trolley wire when in service it can be guarded by an inverted wooden trough or an automatic section insulator.

Having now become familiar with the conditions of service and development, but one item remains, namely, to test the mine cars for resistance due to friction.

In conclusion it is of little value to endeavor to lay out a set mode of proceedure for use at every mine because part of the attraction offered by this class of work lies in its ever changing conditions and consequent modification in the plans for meeting and controlling them.

POWER-FACTOR CORRECTION WITH SYNCHRONOUS MOTORS

WITH CURVES FOR THE ESTIMATION OF REACTIVE EFFECTS

NICHOLAS STAHL

IN LAYING out and operating transmission and distribution systems it is often necessary to calculate the energy and reactive components of the power transmitted and the power-factor of the circuits, in order to learn the conditions under which the equipment is operating or to estimate its probable performance under certain conditions. The various quantities which must be considered frequently assume rather complex relations and thus render such calculations more or less difficult. In order to simplify this work a number of convenient curves have been prepared to show the various relations that commonly arise in practice.

FUNDAMENTAL CONSIDERATIONS

In considering the relations between the currents flowing in inter-connected alternating-current circuits supplying loads of various characteristics, the following fundamental points should be borne in mind*:—

The total current of a circuit may be considered as made up of two component currents, one, in phase with the voltage of the circuit and available for doing mechanical work, and a second bearing a 90 degree relation to the voltage and hence not capable of performing mechanical work. The total current is then the square root of the sum of the squares of the respective components. The 90 degree or wattless component of the current may be lagging with relation to the voltage, due to the presence of inductance in the circuit, or it may lead the voltage, due to the presence of capacity in the circuit. The total or resultant current will be either lagging or leading relative to the voltage, depending upon whether the inductive or capacity effects predominate. If the two elements exactly counterbalance each other the current will be in phase with the voltage, that is the power-factor will be unity or 100 percent. The term "power-factor" serves to indicate the amount by which the current lags or leads the voltage. Power-factor may be expressed as the ratio of power current to total current or, what is equivalent, the ratio of kw to total k.v.a., expressed as a percentage.

The total or combined current of two or more inter-connected or parallel receiving circuits is accordingly the geometric sum or resultant of the currents in the respective circuits, and the total power-factor of the main circuit supplying the power is therefore dependent on the respective component currents of the branch circuits and their power-factors. Hence, to determine the resultant power-factor, the respective currents may be resolved into their real and wattless components, these added to find the total of each component, and the final resultant current and power-factor determined therefrom.

A given load added to a circuit may raise or lower the power-factor

*A discussion of the effect of loads of low power-factor on generator capacity, data on the approximate power-factor of various kinds of loads and notes on the fundamentals of power-factor correction will be found in an article by Mr. F. D. Newbury on " Relation of Load to Station Equipment," in the JOURNAL for July 1911, p-623.

depending upon whether the power-factor of the added load is higher or lower than the previous value. The amount by which it is raised or lowered depends on the magnitude of the added current relative to the total current and also upon the degree by which its power-factor differs from the average.

A wattless component of current which is lagging with respect to the induced voltage has a demagnetizing effect on the fields of any connected synchronous generating apparatus, while a leading wattless component of current tends to increase the field magnetization. Synchronous apparatus such as alternators, rotary converters and synchronous motors may be made to have either an inductive or a capacity effect on the circuit to which they are connected by adjusting their field excitation below or above that required to give a unity power-factor relation between their internal voltage and current.

An inductive load involves a current having a lagging component with a demagetizing effect. To correct for this, magnetization must be supplied either by the generators at the power house or by some synchronous line apparatus capable of operation at a corresponding leading power-factor If sufficient generator capacity is available, the leading or magnetizing current can be supplied with greatest economy by the generators. If, however, the relations between load, carrying capacity of line and generator equipment are such that the entire generator capacity is required to give a maximum real or power current, or if the line is loaded to its capacity so that it cannot economically carry the additional wattless current and its charging current is insignificant, it is then necessary that this leading current be supplied by such other synchronous machinery as may be connected near the load if the total power-factor of the load is to be raised.

When the leading current required to compensate for the demagnetizing effect of inductive loads is supplied by means of synchronous machines near the load and a certain value of power-factor is maintained, not only are the generators relieved of the wattless current, but the transmission lines are also relieved and hence the voltage regulation is improved.
and generators are alone suitable, as rotary converters suffer not only the

Of synchronous machinery for use in improving power-factor, motors common disadvantage of poor efficiency at low power-factors, but for reasons not pertinent to the present article, are inherently liable to dangerous overheating of the coils adjacent to the collector ring taps. A synchronous motor, when thus used, to modify the power-factor of a circuit through the adjustment of its field excitation, is commonly called a "synchronous condenser."

SIMULTANEOUS RELATIONS BETWEEN K.V.A., KW, AND WATTLESS POWER

As the k.v.a., kw, and reactive or wattless power of a circuit bear a definite relation to one another, which can be represented by a right angle triangle in which the hypotenuse represents k.v.a., the other two sides are the kw and wattless components, and the power-factor is the cosine of the angle between kw and k.v.a., it is possible, by means of the curves shown in Fig. 1, to indicate as a percentage the wattless component which corresponds to any given kw or k.v.a. Thus, with any two of these four factors given, the other two may be obtained. The sine curve shows the wattless components expressed in percent of a given *k.v.a.* load corresponding to different power-factors, while the tangent curve shows the

wattless components expressed in percentage of a given *kw* load at various power-factors.

For example, assuming a 2 500 k.v.a. load at 75 percent power-factor. To find the corresponding wattless component; follow the vertical line from 75 on the base line to its intersection with the sine curve and read horizontally to find the corresponding percentage wattless component as 0.66. Then, $2\,500 \times 0.66 = 1\,650$ k.v.a. the wattless component.

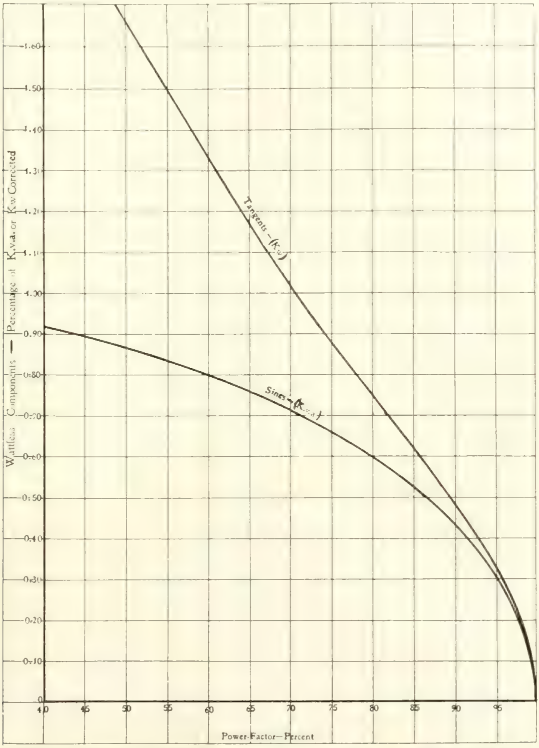

FIG. I—CURVES SHOWING RATIO OF WATTLESS COMPONENT OF A CIRCUIT TO ITS K.V.A. AND KW AT VARIOUS POWER-FACTORS

Or again, if the wattless component is 1 200 in a given case, and the k.v.a. equals 1 800, the corresponding percentage wattless component on the basis of 1 800 k.v.a. would be 0.667 (or $1\,200 \div 1\,800$); then, to find the corresponding power-factor, follow horizontally from 0.667 to the sine curve and the vertical line at this point corresponds approximately to 74 percent power-factor. (The kw components are of course equal to k.v.a. $\times$ power-factor).

If, for another case, the wattless component is 900 k.v.a. and the power component is 600 kw, the percentage wattless component corresponding to 600 kw is given by their ratio as 1.5 or 150 percent; to find the power-factor and k.v.a. From the point on the tangent curve corresponding to 1.50 follow the vertical line through this point to the base line to find a power-factor of 55 percent. The corresponding k.v.a. will be equal to 600 ÷ 0.55 (original kw ÷ power-factor) = 1 092 k.v.a.

EFFECT ON POWER-FACTOR OF THE ADDITION OF VARIOUS LOADS

By the above method the wattless components corresponding to the loads (in kw or k.v.a.) at their respective power-factors, which go to make up the total load on a given circuit can be quickly determined. In order to determine the resultant power-factor of a total load, add all of the wattless components, divide their sum by the sum of all the kw components, and from this ratio and the tangent curve of Fig. 1 determine the corresponding power-factor.

For example, assume an incandescent lamp circuit aggregating 200 kw and having a power-factor of 98 percent, a 100 k.v.a. synchronous motor at 100 percent power-factor, several induction motors totaling 300 kw at 80 percent power-factor, and arc lamps to the total of 150 kw at 70 percent power-factor; further let the line at 95 percent power-factor have an energy loss of 10 percent with this condition of loading, or ten percent of (100 + 200 + 300 + 150) = 75; then the several reactive components are read from the curves of Fig, 1 as follows:—In the case of the lamp circuit at 98 percent power-factor, follow the perpendicular from the point corresponding to 98 to its intersection with the curve marked "tangents"; this point will then be found at 0.204, etc. Then

Incandescent Lamps	200 × 0.204 =	40.8
Synchronous Motors	100 × 0 =	0
Induction Motors	300 × 0.75 =	225
Arc Lamps	150 × 1.02 =	153
Line	75 × 0.328 =	24.6
Total Kw	825	
Total Wattless Component		= 443.4

Then 443.4 ÷ 825 = 0.537, which corresponds, on the tangent curve of Fig. 1 by means of the sine curve and the resulting power-factor found by required to supply the circuit would be 825 ÷ 0.88 = 938 k.v.a.*

Had the several loads been specified in terms of k.v.a. instead of kw, the corresponding reactive components could have been worked out from Fig. 1 by means of the sine curve, and the resulting power-factor found by a similar process.

EFFECT ON POWER-FACTOR OF ADDITION OF NON-INDUCTIVE LOADS

The curves of Fig. 2 serve to indicate the effect on the power-factor of a given load of the addition of non-inductive loads, such as an incandescent lighting load or rotary converters (which operate most economically and safely at 100 percent power-factor), especially when the added load is a considerable proportion of the

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*A 1 000 k.v.a. machine at 90 percent power-factor would therefore be more than sufficient to carry this load, even if all of the load were connected at one time. Under the more probable conditions of ordinary operation ,a 750 kw machine would be ample.

total. The power-factor is improved even though no leading wattless component is introduced. To apply the curves, let P equal the original load (in kw) whose power factor it is desired to raise, and let L be the added non-inductive load. Then find the ratio $L \div P$ and apply the curves as follows:—

For example, a 500 kw rotary converter is connected to a central station which already has a load of 1 200 kw at 70 percent power-factor. The ratio of 500 to 1 200, or $L \div P$, represents the percentage added load or 41.7 percent. Following horizontally from the ordinate of Fig. 2 at 0.417 to the curve for 70 percent power-factor, read down vertically to find a resulting power-factor of 81 percent.

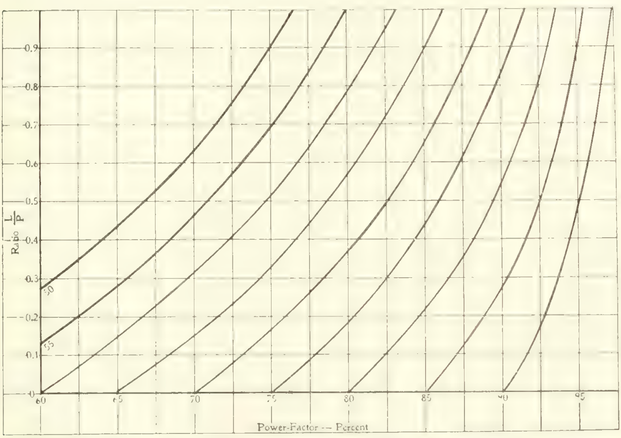

FIG. 2—POWER-FACTOR OF CIRCUIT RAISED BY ADDITION OF NON-INDUCTIVE LOAD

Given the ratio of added non-inductive load L to original load P (kw) and original power-factor, the final power-factor is determined directly from the curves.

Conversely, if a given percentage correction is sought by the use of added non-inductive load, for example to raise 800 kw from 60 to 75 percent, read horizontally on Fig. 2 from the intersection of the perpendicular erected at 75 with the 60 percent curve to find an ordinate of 0.518, which represents the percentage kw load required. Then the added non-inductive load required would be $800 \times 0.518 = 414.4$ kw.

The curves of Fig. 2 show the relatively greater effectiveness of the addition of a non-inductive load to a circuit having a low power-factor than to one having a higher power-factor, especially when the percentage added is small.

For example, if to a load having a 60 percent power-factor a non-inductive load of one-tenth the amount be added, the power-factor will be raised to 63, whereas the same percentage added to a load at 90 percent power-factor would raise the power-factor to only 91.66 percent.

EFFECT OF SYNCHRONOUS CONDENSER WITH THE TOTAL LOAD MAINTAINED CONSTANT

Power-factor correction by an "idle" synchronous condenser, i.e., one not carrying mechanical load, may be calculated at once from the curves of Fig. 3, if the load is specified in kw, by starting at the base line of the curves at the point corresponding to the original power-factor, following this curve to it intersection with the vertical line at a point corresponding to the desired power-factor, and reading horizontally from this point to the corresponding ordinate at the left which denotes the percentage wattless component required of the synchronous condenser. The actual value of k.v.a. is then the product of the kw load multiplied by this percentage.

If the load is expressed in k.v.a., the corresponding wattless component is obtained in a similar manner from Fig. 4.

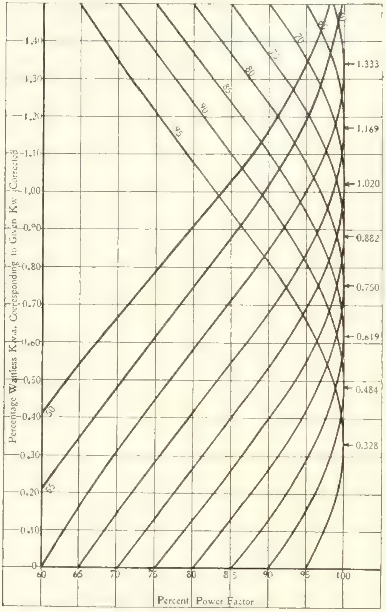

FIG. 3—CURVES SHOWING AMOUNT OF WATTLESS COMPONENT REQUIRED TO RAISE POWER-FACTOR OF GIVEN KW LOAD TO REQUIRED HIGHER VALUE

The wattless components are expressed as percentages of the original kw load. The numbers at the right which indicate the points of tangency of the power-factor curves to the 100 percent line show the amount of wattless component required to raise a given kw load of given lagging power-factor to unity power-factor. Obviously the addition of further wattless component in a given case would result in a leading power-factor less than unity.

Explanation of Corrective Effect of Synchronous Condenser — When the field excitation of a synchronous motor used for power-factor correction is other than that required to give a counter-e.m.f. equal to the impressed e.m.f. with the armature current in phase with the voltage (i.e., the motor operating at 100 per-

cent power-factor), the magnetizing effect of the resulting wattless current combined with the magnetizing effect of the field current produces a constant magnetic field in the armature. When a synchronous motor is over-excited there is therefore a resultant leading wattless or demagnetizing component of its current which neutralizes the over-excitation and which is effective in raising the power-factor of the connected load, as the line current is the vector sum of the individual currents in the respective apparatus, and a change in the power-factor of one component brings about a certain resultant variation in the total.

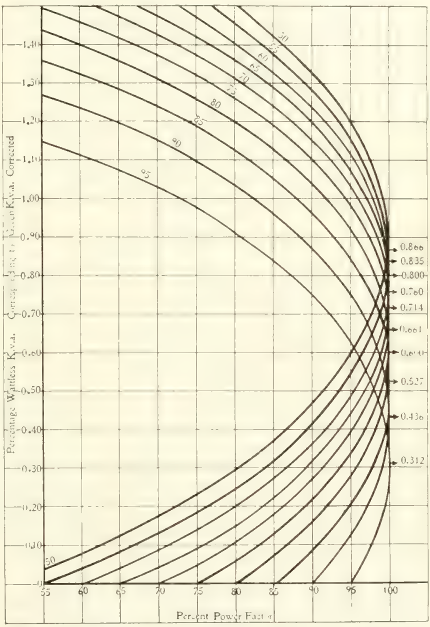

FIG. 4—CURVES SHOWING AMOUNT OF WATTLESS COMPONENT REQUIRED TO RAISE THE POWER-FACTOR OF A GIVEN K.V.A. LOAD TO A REQUIRED HIGHER VALUE

Similar to the curves of Fig. 3, except that the wattless components are expressed as percentages of the original *k.v.a.* load.

If the sides of the triangle *ABC*, Fig. 5, represent the k.v.a., kw, and wattless components of power respectively, with an initial power-factor of Θ_1 (i.e., the ratio of kw to k. v. a. = $AC \div AB$), then connecting in a motor of rated capacity *BX* will raise the power-factor to Θ_2 (or $AC \div AX$, Fig. 5), if the whole capacity is used for condenser effect, assuming constant kilowatts transmitted (and disregarding the no-load losses in the motor). When the installation has already been made the problem may be that of raising the power-factor on a given kilowattage, as indicated in this figure. On the other hand,

where the apparatus and line are not yet in place, the operator will be interested in learning the greatest power he can transmit with a fixed k.v.a. for which case Fig. 6 is applicable. Figs. 5 and 6 also indicate the basis on which the curves of Figs. 3 and 4 are drawn.

CORRECTION BY IDLE CONDENSER, WITH LOAD ADDED

Generally the correction of power-factor is desired not only for existing loads of given kw or k.v.a., but to bring the total power-factor up to a certain value after connecting an additional load, say of induction motors or rotary converters, to the circuit. The case presented is then to obtain the vector sum by the method given under the heading "Effect on Power-factor of the Addition of Various Loads" and use the resultant kw or k.v.a. for the basis of the correction desired. The size of synchronous condenser required to give the necessary leading wattless component may be deter-

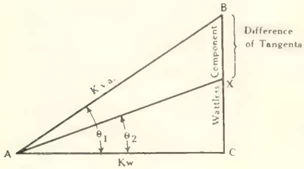

FIG. 5
Power-factor of a given kw load raised from Θ_1 to Θ_2 by the addition of a leading wattless component *BX* supplied, e. g., by a synchronous condenser.

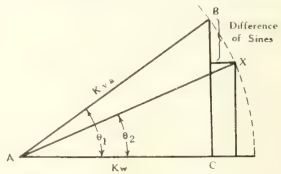

FIG. 6
Power-factor of a given k.v.a. load raised from Θ_1 to Θ_2 by the addition of a leading wattless component *BX*. (Figs. 5 and 6 represent graphically the conditions of Figs. 3 and 4).

mined by means of Fig. 3 or Fig. 4, by assuming the new value of kw or k.v.a. to remain constant.

CORRECTION WITH LOAD ADDED, THE SYNCHRONOUS CONDENSER ALSO SUPPLYING MECHANICAL POWER

Under this head five problems may be solved:—

1—For an assumed load P, at an assumed power-factor F_1, given also the mechanical output L desired from the synchronous condenser; to find the k.v.a. rating M of a machine which will raise the line power-factor to a given value F_2.

2—Given the rating of the condenser, and its required mechanical output; to find the increase in power-factor which may be effected by its use.

3—Given the rating of the condenser; to find the maximum

mechanical load which it will carry while giving maximum corrective effect, or vice versa.

4—Given the rating of the condenser and the correction to be made; to determine the mechanical output it can also effect.

5—With synchronous motor kw and wattless components equal.

1—Considering first the additional load mentioned, determine the total k.v.a or kw, exclusive of the synchronous condenser or its load, and find the corresponding power-factor.

For example, assume an original load of 1 500 k.v.a. at 80 percent power-factor, or 1 200 kw, to which is to be added the following loads:—200 kw in arc lamps at 70 percent power-factor, 300 kw in rotary converters at 100 percent power-factor, 240 kw in induction motors at 75 percent power-factor, and a synchronous condenser mechanical load equivalent to

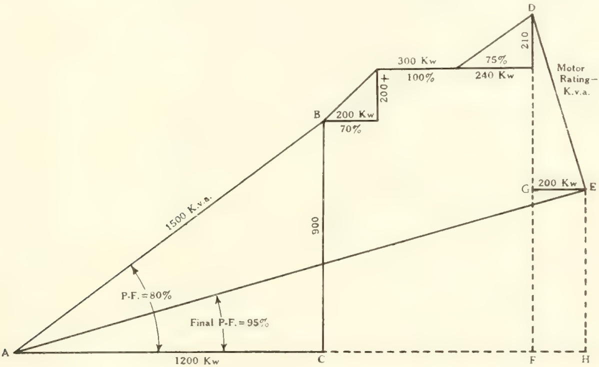

FIG. 7—VECTOR DIAGRAM ILLUSTRATING THE GRAPHIC SOLUTION OF A PROBLEM IN POWER-FACTOR CORRECTION, AND SHOWING THE RESPECTIVE K.V.A., KW, AND WATTLESS COMPONENTS INVOLVED AND THE CORRESPONDING POWER-FACTOR RELATIONS

200 kw; to determine the required rating of the synchronous condenser which will give a final power-factor of 95 percent. Fig. 1 gives the corresponding lagging wattless components as 900, 200, 0 and 210, respectively, or a total of 1 310. The corresponding power components make a total of 1 940 kw. The method of adding the respective components graphically is shown in Fig. 7. The ratio of total wattless to total kw components, i. e., 1 310 ÷ 1 940 equals 0.677 which is the total wattless component expressed as a percentage of total kw load. Then the tangent curve of Fig. 1 indicates a corresponding power-factor of 82.5 percent. The total power or kw load, including that of the synchronous motor, or *AH*, Fig. 7, will be 2 140 kw, which will involve at a final power-factor of 95 percent, a wattless component $HE = FG$ or 0.329 (obtained by means of Fig. 1) $\times 2\,140 = 705$. The difference between this and the previous wattless component (i. e., $1310 - 705$) is 605 or *DG*. The motor rating can now be found from Fig. 1. Thus $200 \div 605 = 0.33$ which in Fig. 1 corresponds on the "tangent" curve to 95 percent power-factor and $605 \div 95 = 637$ k.v.a., the required output of the synchronous motor.

2—Given original load and power-factor, motor rating and its mechanical load; what power-factor can be obtained? Determine the motor wattless component by means of Fig. 1 and divide this amount by the number of kilowatts to be corrected, to obtain the percentage wattless; then, from Fig. 3 find the power-factor thus obtainable. The motor is, however, able to bring about a higher power-factor than the one thus found on account of the mechanical load carried, as is shown by Fig. 2, from which the total correction or final power-factor is obtained.

For example, assume the original load P equal to 1 800 kw at 60 percent power-factor, and a motor M rated at 1 000 k.v.a. which is to carry 500 kw load L; to find the resulting power-factor. The motor power-factor will be $500 \div 1\,000 = 50$ percent. Then Fig. 1 gives the motor wattless component as 0.866 which, on the basis of 1 000 k.v.a., equals 866 k.v.a. Dividing this by 1 800 gives the ratio of motor wattless component to kw power corrected, or 0.481. Fig. 3 shows that the effect of this wattless component will be to raise the power-factor from 60 to, roughly, 76 percent. The ratio of motor load L to original load P is $500 \div 1\,800$ or 0.28. Starting then from the ordinate 0.28 of Fig. 2, pass horizontally to intersect the curve which would be drawn from 76 percent power-factor and read vertically downward to find a final power-factor of 83 percent.

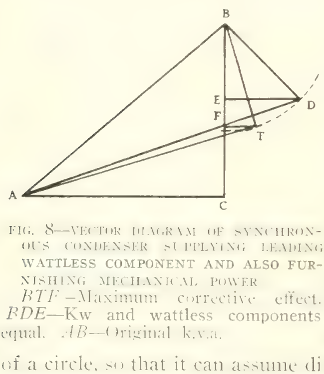

FIG. 8—VECTOR DIAGRAM OF SYNCHRONOUS CONDENSER SUPPLYING LEADING WATTLESS COMPONENT AND ALSO FURNISHING MECHANICAL POWER

BTF—Maximum corrective effect. *BDE*—Kw and wattless components equal. *AB*—Original k.v.a.

3—Manufacturers are usually prepared to quote on certain standard capacities of synchronous motors. Accordingly, a special case of interest involves the question of the *maximum* power-factor improvement that may be effected from a given synchronous motor. The corresponding mechanical load on the motor is to be determined simultaneously with this maximum betterment.

Fig. 8 shows the motor rating M (in k.v.a.) as the radius of a circle, so that it can assume different directions according to the amount of mechanical motor load L carried; it is clear that the maximum power-factor of the system will be obtained when the final k.v.a. line is tangent to the circle; under this condition the resulting power-factor is given by the expression: (Original kw + motor kw) $\div \sqrt{\text{original k.v.a.}^2 - \text{motor k.v.a.}^2}$, (or referring to Fig. 8, $\text{P-F} = (AC + FT) \div \sqrt{AB^2 - BT^2}$), and the mechanical load is equal to the motor rating multiplied by the sine of the final power-factor angle, this sine value being obtained at once

from Fig. 1. It will be observed that better power-factor can be secured with a motor simultaneously carrying a certain mechanical load than where its entire k.v.a. load is used for corrective purposes. This mechanical load includes, of course, the no-load losses of the motor, which would have to be subtracted to indicate the net mechanical output.

These results can be obtained more simply by means of the curves in Fig. 9. With their use it is necessary only to find the ratio of the motor rating M to the original k.v.a. (not kw), which is called K. With this ratio as a starting point at the base line, follow a vertical line to the curve starting from the original power-factor, and from their intersection read horizontally to find the final power-factor; at the same time pass horizontally to meet the curve marked L, and from this new point downward find the numerical value of the sine corresponding to the final power-factor angle, which value it is only necessary to multiply into the motor rating to secure the mechanical load which may be obtained simultaneously.

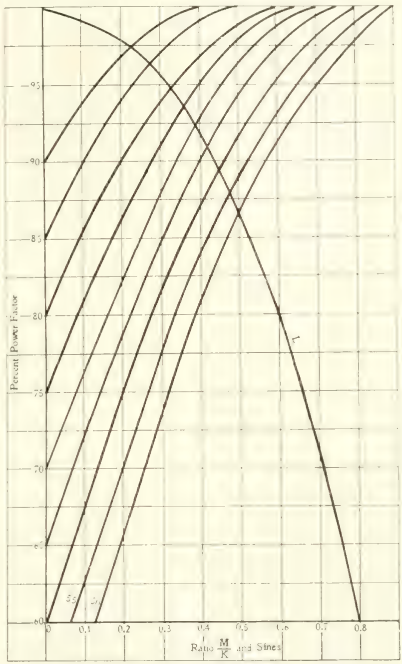

FIG. 9—CURVES FOR DETERMINING MAXIMUM POWER-FACTOR IMPROVEMENT WHICH CAN BE OBTAINED WITH GIVEN K.V.A. ORIGINAL LOAD AT GIVEN POWER-FACTOR AND SYNCHRONOUS CONDENSER OF GIVEN K.V.A. RATING; ALSO, THE MECHANICAL LOAD WHICH THE CONDENSER WILL CARRY SIMULTANEOUSLY.

K=Original k.v.a. load. M=motor k.v.a. rating; mechanical load L being expressed as a percentage of the motor k.v.a. rating.

For example:—original load = 1 600 k.v.a. at 60 percent power-factor; motor rating = 400 k.v.a. $\frac{M}{K} = 0.25$. Final power-factor = 77 and motor mechanical load = 400 × 0.62 = 248 kw.

4—Given the initial load *P*, the initial and final power-factors, F_1 and F_2, and the motor rating *M*; required to find the mechanical load which may be carried by the motor. The general answer to this question is not as simple as the foregoing. However, the following may be used as an approximation. If the motor is operated at 100 percent power-factor the final total power-factor obtainable may be determined at once by means of Fig. 2. An approximate estimate may then be obtained regarding the possible amount of wattless component that will have to be supplied by the motor in order to reach the desired power-factor; in some cases it will be found that operation at its full k.v.a. and unity power-factor will give greater corrective effect than required. Again, the corrective effect of the motor, if operated entirely as a condenser, is estimated at once from Fig. 3. Further Fig. 9 indicates at once the *maximum* corrective effect which can be secured. From these considerations, a fairly accurate approximation can be made of the motor load when the desired power-factor is secured.*

5—Kw and Wattless Components of Motor Equal—The maximum obtainable power-factor correction is secured with relatively small mechanical load compared with its k.v.a. rating, as already shown in connection with Fig. 8. When the installation of a machine for power-factor correction is considered, it is not uncommon to estimate the k.v.a. which may be applied wattlessly, and the kw output of the machine as of equal value. On such a basis the maximum effectiveness of a motor is secured when its power-factor is approximately 70 percent, as its wattless k.v.a. and kw components are then equal. With this understanding the mechanical load which must be carried by the motor in order to produce a given change in power-factor is obtained as a percentage of the kw load corrected by means of Fig. 10. As the motor power-factor is accordingly approximately 70 percent, the k.v.a. rating of the motor may be obtained when its kw component is known by referring to

*This last problem is added for the sake of generality, though in most cases the operator will have a certain load which must be taken care of, and the power-factor secured will be considered as a matter of secondary though actually of real, importance. Very rarely will it be specified that a certain power-factor must be secured, and then the corresponding load arranged for accordingly.

Fig. 1 to obtain the sine value corresponding to 70 percent power-factor (equal to 0.705) which divided into the motor kw gives its k.v.a. rating. It may be noted that this latter is equivalent to multiplying the kw value by 1.41 (i.e., $\sqrt{2}$).

Thus, for example, with a motor carrying a mechanical load equal to its wattless component, what size motor is required to raise a load of 1 800 kw from 60 to 90 percent power-factor? Follow the curve of Fig. 10 originating at 60 percent power-factor to its intersection with the vertical passing through 90 percent power-factor and read horizontally at the left the required percentage motor kw per kw corrected load, i. e., 0.57, which multiplied by 1 800 gives the total motor load required, or 1 025 kw. This value multiplied by 1.41 gives final motor rating as approximately 1 450 k.v.a.

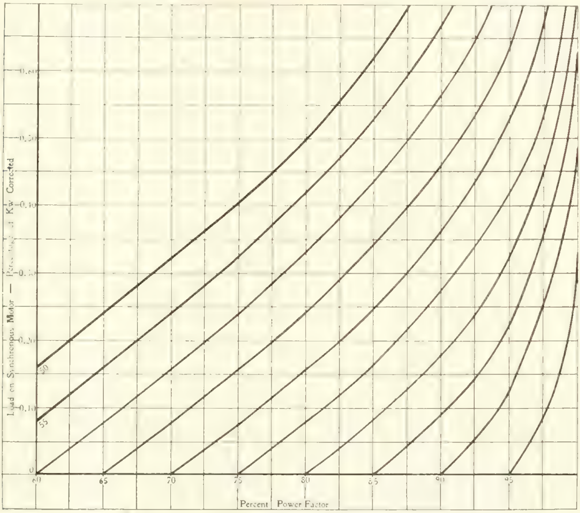

FIG. 10—CURVES FOR DETERMINING MECHANICAL LOAD ON SYNCHRONOUS CONDENSER CORRESPONDING TO REQUIRED POWER-FACTOR IMPROVEMENT AND CORRESPONDING K.V.A. RATING OF CONDENSER, ASSUMING KW AND WATTLESS COMPONENTS OF CONDENSER EQUAL.
Mechanical load expressed as percentage of original kw corrected.

In a specific case such as that of a transmission line carrying power to a centre of distribution from which radiate branches loaded at various power-factors, whether or not the most efficient arrangement will be obtained by raising the power-factor by means of a synchronous motor located at the junction point, or by improving primarily one or more of the branches of lowest power-

factor, is a question requiring individual, and sometimes extended consideration; improvement in any branch affects the whole line back of the junction point and indirectly the other branches as well.

As long as the power-factor is not corrected beyond 100 percent, all of the foregoing general conditions obtain, but beyond 100 percent (i.e. with a leading power-factor) if mechanical power is also to be drawn from the motor, a very large increase must be made in its k.v.a. input to secure any considerable change in power-factor. It then becomes necessary to determine whether the mechanical power gained, when capitalized at the coal pile, due allowance being made for first cost, maintenance, depreciation, etc., is worth more than a similar valuation of the increased line losses, line drop, copper for transmission, losses in generators, *decreased* load factor with corresponding efficiency loss, etc. In general it will be found that, where the first proposed k.v.a. of the motor is comparable with the original total power transmitted, the gain in mechanical output will much more than compensate for the slight reduction in power-factor (leading) involved. Usually the question of over-correction will not be met; as the average operator desires merely to improve the lagging power-factor toward 100 percent. Nevertheless, if a large increase in load of low power-factor is contemplated the installation of a motor capable of over-correction may be found desirable.

This does not mean, of course, that the motor need be so operated as to cause over-correction, as this can be obviated in one of three ways. First, by decreasing the excitation, which will decrease the leading wattless component and hold the mechanical load constant. The motor will then have the advantage of a decreased k.v.a. Second, by throwing off the mechanical load and decreasing the excitation, the resultant effect of the motor may be brought to the point where, for example, 100 percent power-factor on the system ensues, either with the same or a lessened motor input, depending on the constants of the system. Third, by decreasing the excitation and increasing the mechanical load, the system may with suitable constants be brought to 100 percent power-factor as desired, without altering the k.v.a. motor input. In the first instance, the square of the motor k.v.a. equals the sum of the squares of the mechanical load and the original wattless component, respectively, of the system; in the second instance, the motor operates as a "condenser" with its k.v.a. equal to the original wattless component of the system; in the third instance, the square of the new mechanical load is equal to the difference of the squares of the motor rating and original wattless component respectively, of the system. All of these quantities discussed are readily found from Fig. 1.

It may also be noticed that long transmission lines frequently require of their generators, at times of light load, a very considerable leading capaciy or "charging" current, which has been known to amount to as much as 40 percent of the k.v.a. generator capacity. In the case of a long high voltage line involving relatively small power capacity, the generator might even be seriously overloaded as a result of the leading wattless k.v.a. required to charge the line. Under these conditions, the synchronous motor

may be run under-excited, so as to demand a lagging current to compensate for the charging current. In this case the wattless components of the line and load currents are the reverse of the above cases whether the motor is carrying mechanical load or not, and may be solved accordingly.

However, as will be evident from an inspection of the curves of Figs. 2 and 3, the amount of betterment to be secured with a given kw transmitted and the motor furnishing a definite wattless component, is decidedly less in the region of 100 percent power-factor than elsewhere. Hence it is evident that in ordinary cases it is not economical to attempt to raise the power-factor of loads of reasonably high power-factor.

For example, to change 1 000 kw from 60 to 65 percent power-factor requires 165 k.v.a. (wattless component), but from 95 to 100 percent, 329 k.v.a. or twice as much. From 75 to 85 percent, 26 k.v.a. wattless component is required for each percent change of power-factor; from 98 percent lag to 98 percent lead requires 105 k.v.a. for each percent change.

SELECTION OF ALTERNATING CURRENT APPARATUS

A method has already been given for obtaining the final power-factor of a system after the addition or subtraction of various loads of given characteristics. By this method, and with the aid of Fig. 1, an estimation of the required k.v.a. capacity of a generator or the required ratings for motors or other apparatus to suit certain conditions can readily be obtained. For example, assume a case where it is desired to add an induction motor load of certain capacity to a circuit having a load of given power-factor well within the capacity of the generator. The relative effects of various combinations of motors may thus be readily investigated, taking into consideration not only the mechanical load but the operating power-factor and efficiency of either the individual motors or the added load considered as a unit, with a view to determining whether the generator would be overworked with the additional load. The same considerations apply of course to other apparatus, the more or less successful operation of which depends on the operating power-factor.

The disadvantages of operating generators on loads of low power-factor, when their available k.v.a. capacity is required for the generation of useful kw power, have already been mentioned; if, however, the generators and transmission lines are not fully loaded, the corrective effect can often be furnished most economically by the generators direct, instead of installing extra synchronous motors for this purpose.

GENERATOR FIELD CURRENTS

It is often desired to know the variation in field current required for a given generator to maintain normal voltage under various power-factor conditions. This knowledge may be needed in order to determine the field heating, or in connection with the selection or checking of exciter capacity for either hand or automatic regulation, such as with Tirrill regulators. This can be readily determined for a given machine by means of a set of simple tests, the results of which are used in connection with Fig. 11.

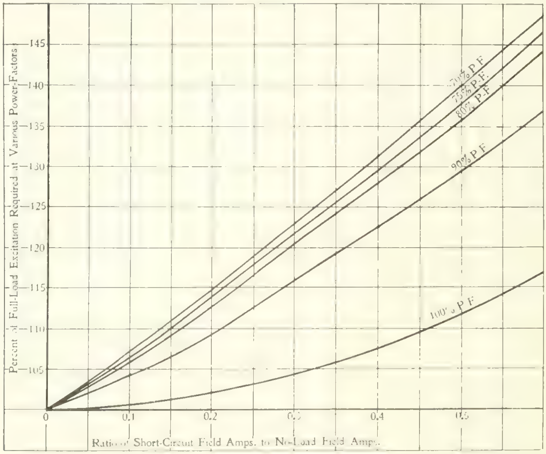

FIG. 11—CURVES FOR DETERMINING APPROXIMATE EXCITATION REQUIRED BY ALTERNATORS AT VARIOUS POWER-FACTORS

Based on simple running tests to obtain field currents corresponding to full load current with armature short-circuited and to normal open-circuit voltage.

With the machine operating at normal speed as a separately excited generator the field current required to cause full-load current to flow in the armature when short-circuited may be readily determined by test. The field current required to give normal voltage at no-load obviously may also be determined by a simple running test. The ratio of the "short-circuit" field current, referred to above, to this latter value of field current may now be used in connection with Fig. 11 to determine from the curves the total field current required to give normal voltage with full load at 100 percent or any other power-factor within the range of the curves.

For example, if on a given machine the field amperes necessary for no load excitation are 95 amperes while the short-circuit test at full load current (the synchronous impedence test) indicates that a field current of 19 amperes is required, the ratio of these two quantities used in connection with the curves of Fig. 10 (i. e., 0.2) determines the total field current for full-load operation at normal voltage as 102 percent of 95 or 97 amperes at 100 percent power-factor; 108.5 percent of 95 or 103 amperes at 90 percent power-factor; 112.5 percent of 95 or 107 amperes at 80 percent power-factor, and 114.5 percent of 95 or 109 amperes at 70 percent power-factor, etc.

The vector relations of the voltages corresponding to these respective field currents are shown in Fig. 12. At 100 percent power-factor the line CB is approximately at right angles to AC, as indicated by the dotted line CB^1. Fig. 11 thus shows the effect of low power-factor in increasing the field current required to maintain normal voltage, and it will be noted from it as well as from Fig. 12 that the increase needed for a given change of power-factor below say 70 percent is relatively small compared with an equal change of power-factor between 70 and 100 percent. It will be

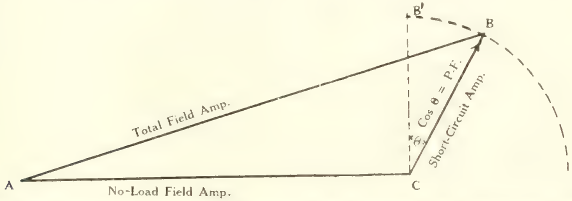

FIG. 12—DIAGRAM INDICATING RELATIONS OF VOLTAGES OF ALTERNATOR AT VARIOUS POWER-FACTORS

Basis of the curves of Fig. 11.

seen further from Fig 12 that the increase in excitation required at any power-factor is proportional to the amount of synchronous impedance, represented by the line CB, as determined by the synchronous impedance or short-circuit test; that is, it is practically, proportional to the inherent reactance of the machine, (neglecting the ohmic drop due to full-load current in the short-circuit test). This means that a machine with high armature reactance will have relatively poor regulation. However, high reactance is an advantage in case of short-circuit on a machine, as it serves to limit the current flow and the attendant mechanical shock to the windings.

In conclusion it should be pointed out that while the foregoing curves have been applied to the solution of specific problems, they are quite general in their application, and should be of considerable use in the solution of other problems in reactive effects not considered here, but such as arise in theory or practice.

NOTES ON ELECTRIC LOCOMOTIVE CONSTRUCTION

L. M. ASPINWALL

THE design and equipment of a modern high power electric locomotive probably involves a greater diversity of engineering problems than is embodied in the construction of any other electric machine. All parts entering into the construction are so intimately related that, to get the best results, it is desirable that each piece of apparatus be designed for the particular class of locomotive for which it is to be used. The design of an electric locomotive generally requires the separate consideration of all of the distinct systems,—the mechanical parts, the main electrical propulsion system, the braking system, the ventilation system and the collector system. All of these systems are separate and distinct, but are as closely related as the various parts of the human body, and to obtain harmonious operation their effect upon each other must be carefully considered.

In the early days of the equipment of electric cars, before locomotives came into common use, it was generally a case of whether the electrical man or the air brake man got to work on the car first as to which one was able to locate his apparatus to advantage. If the air brake man started first, he usually located his apparatus to the best possible advantage without regard to the electrical equipment and the electrical man had to be content with the remaining space or fight for every additional inch he required. If the electrical man emphasized the importance of his equipment, he was met with the statement that the air brake equipment is the most important, for it is easy enough to start a car, but very hard to stop it.

Fortunately for the modern electric locomotive, the electrical, mechanical and air brake man have now learned the value of cooperation. In designing a modern electric locomotive the first step, of course, is to gather full data as to the service which it is required to perform. When it is known just what the locomotive is to pull, the speed at which it must travel, how long its must sustain this service, etc., then the vital part, the motors, can be settled upon. The design and type of the motor may be said to be the pivotal point of the structure, for the design of all the other parts is affected thereby to a greater or less degree.

The mechanical parts must be designed to accommodate the motors; the control apparatus and the main wiring must be designed to carry the currents required by the motor, the size of blowers (if any are used) is determined by the air required for the

motors; the form and capacity of brakes required are modified by the inertia of the rotating parts of the motor, etc.

Assuming that the various pieces of apparatus for a locomotive have been designed, the next step is to decide upon the general assembly of the parts on the running gear and in the cab, or the "layout of apparatus," as it is termed. Laying out a locomotive equipment is very similar to laying out a power house, except that it is, unfortunately, more difficult on account of the limited space. In the early days of car equipments it used to be considered a satisfactory way of doing this work to get all the apparatus together near the car, then to mount a piece of apparatus here and a piece there as seemed desirable until the whole was assembled. The foregoing method answered fairly well in the case of small, old-style equipments, but it is certainly not engineering and cannot be tolerated in the equipment of a modern high powered locomotive.

The old saying "mistakes in iron are serious," is still very true, and the only way that such errors can be avoided is by making a careful study of the layout of apparatus on the drawing board. The preliminary layout can best be settled upon by making small-scale cardboard templets of the various important parts of the equipment and determining their best location by the cut-and-try method on a scale outline drawing of the locomotive. Considerable time and study can be put in to advantage with this templet game, but after a good layout has been obtained and penciled in, the designer should not by any means delude himself with the idea that the work is done, for, as a matter of fact, he is only just in a position to start on the real work of design.

A carefully made scale drawing should now be prepared, not less than one-eighth inch to the foot, with all the various pieces of apparatus drawn in carefully to scale in the positions planned on the preliminary templet layout. It is important that the outlines of apparatus be made accurately and that they show all projecting parts and all inlets or outlets for cables, pipes, etc., in order to avoid interferences. After the apparatus has been drawn in, it is necessary to design the necessary hangers and supports, then to plan the runs of conduit, piping and cables. It is generally found necessary to modify considerably the preliminary layout when it comes to the point of making the actual working drawing, and it is right here that the mistaken economy of trying to do the actual work from a preliminary layout becomes evident. Every hour properly devoted to layout work in the drawing office saves many times its cost in the shop when equipping a number of locomotives.

EXPERIENCE ON THE ROAD

A TIRRILL REGULATOR WITH SEVERAL INDEPENDENT SOURCES OF CONTROL

J. W. WELSH

One of the principal requirements for the successful operation of a Tirrill voltage regulator for alternating-current machines is that there shall be no interruption in the circuit of the alternating-current control magnet. In other words, the alternating-current control magnet must continuously have applied to it the voltage which the regulator is controlling. As this circuit may contain a potential transformer, high tension fuse holders, (the fuses being replaced with copper wire), a switch for connecting the regulator to one circuit or to another, and an adjustable resistance for changing the voltage setting, there is always a

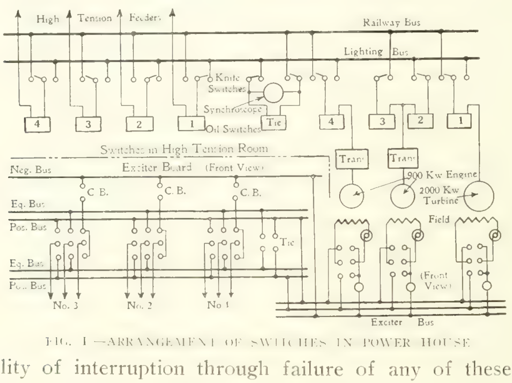

FIG. 1—ARRANGEMENT OF SWITCHES IN POWER HOUSE

possibility of interruption through failure of any of these parts. Moreover, when one regulator controls the bus-bar voltage of a large station employing the double bus-bar, or group, system of distribution, an additional risk is incurred due to the possibility of the bus-bar or group to which the regulator is connected getting in trouble or becoming separated, thus putting the control of the voltage for the entire station out of commission.

The method described below was tried out and found satisfactory at the Glenwood power station of the Pittsburgh Railways Company. The alternating-current generating equipment at this station consists of a 2 000 kilowatt turbine and two 900 kilowatt engines. The arrangement of the high tension bus-bars and feeders is shown in Fig. 1, the three phases of each bus-bar and cable being represented by a single line. One Tirrill regulator is connected

to the railway bus-bar and another Tirrill regulator is connected to the lighting bus-bar. In normal operation the turbine generator and feeders Nos. 3 and 4, supplying the railway load, are connected to the railway bus-bar. The two engine generators and feeders Nos. 1 and 2 are connected to the lighting bus-bar. The bus-bar tie switch is ordinarily kept closed, however, since it is not economical to run with the units separately loaded and is moreover unnecessary from the standpoint of voltage regulation. As only one Tirrill regulator is necessary when the machines are connected together, it was customary to put one of the generators ordinarily connected to the lighting bus-bar in operation, the other being kept as a spare. In changing units from one bus-bar to another it was obviously necessary for the operator to see to it that the regulator and machines were not separated.

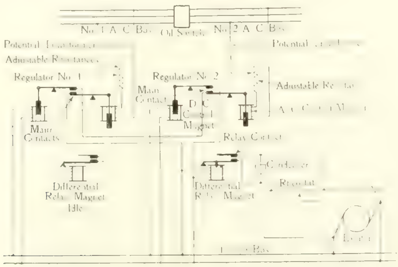

FIG. 2—CONNECTIONS FOR USING TWO SETS OF CONTROL MAGNETS ON TIRRILL REGULATOR

In order to provide a safeguard against any of these risks, a method of combining the control magnets and main contacts of two regulators was devised by which there would be two independent sources of alternating-current voltage, either of which would be at all times instantly operative in case of failure of the other. The wiring diagram of the regulators is shown in detail in Fig. 2. The arrangement consists briefly in connecting the main or floating contacts of two regulators in series, the direct-current and the alternating-current control magnets of both regulators being connected to their respective circuits in the usual way; and the relay magnet which controls the short-circuiting of the exciter field resistance is connected in circuit on one regulator only. From the connections indicated it may be seen that the relay magnet will be actuated only when both sets of main contacts are closed. If the control circuit

on one regulator is interrupted, the main contacts on this regulator will close and stay closed, thereby allowing the main contacts on the other regulator to control the voltage.

When this method of control was first placed in operation, it was checked by a test in the following manner: An adjustable resistance was connected in the alternating-current control circuit of each regulator, such as is ordinarily used for making a change in the voltage setting. This resistance had a value of about 8.5 ohms and was divided into 25 points, each giving a variation of about one-half volt. Both regulators were connected to the same alternating-current bus-bar and the voltage applied to their alternating-current control magnets was adjusted by rheostats in the following manner:—The resistance on No. 1 regulator was cut in, thus lowering the voltage applied to its control magnet until the main contacts remained closed. Regulator No. 2 was then placed in service in the usual manner; viz., by closing the regulator switches and adjusting the exciter rheostat to the customary point, causing the contacts to start working in the usual way.

To transfer the control of the voltage from No. 2 to No. 1 regulator, the resistance on No. 1 was cut out, thus raising the voltage applied to its control magnet and at the same time the resistance on No. 2 regulator was cut in, thus lowering its impressed voltage. The main contacts on No. 2 regulator closed after the above adjustment and those on No. 1 regulator began working. In this way, by adjusting both resistances, there was a minimum resulting change in the bus-bar voltage.

The method was then reversed by raising the voltage applied to No. 2 regulator and at the same time lowering that on No. 1. This caused the contacts on No. 1 to close and those on No. 2 started working. This demonstrated that the main contacts of the control magnet having the lower impressed alternating-current voltage will remain closed, allowing the other one to do the regulating.

The great advantage of this method is the duplication of the most important link of the Tirrill regulator; i.e., the alternating-current control circuit, and consequently the prevention of an abnormal rise in alternating-current line voltage which would naturally follow the interruption of this circuit in case one regulator only was installed. Of course a similar result might be secured by the use of a regulator specially constructed to give this double protection but in this case it was thought desirable to have the entire duplicate regulator available.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

618—Rear Motor Taking Current First—In starting a car while on a curve, on an up grade on bad rails, or when otherwise starting under difficulty, and with the controller in the series position, we have always noticed that the motor on the rear truck spins its wheels while the motor on the forward truck seemed to be taking very little current if any, until the controller was moved to the multiple position. Will you please explain? W. H. M.

We assume that the cars referred to are double truck cars, each truck having one motor geared to the inner axle. Under these conditions the tractive effort of the motors increases the pressure between the rail and the driven wheels on the leading truck, and decreases the pressure between the rail and the driven wheels on the trailing truck. The tractive effort which a motor can exert being proportional to this pressure between the rail and the driven wheels, the trailing truck wheels will always be the first to slip on this type of cars, unless the leading truck happens to be on a particularly slippery spot in the track. This action is explained in detail in an article on "Weight Transfer in Electric Cars and Locomotives" in the JOURNAL for March, 1911, p. 257. G. M. E.

619—Motor Field Rheostat Replaced by Speed Controller—It is desired to replace the ordinary starting rheostat of a shunt motor with a speed controller. What data does a controller manufacturer need to supply a controller for that purpose? P. J.

Supply the following data: 1—Horse-power and voltage of motor; 2—Whether shunt or compound wound; 3—resistance of shunt field winding; 4—shunt field amperes at minimum speed; 5—shunt field amperes at maximum speed; 6—if 3, 4 and 5 cannot be given, give the make and serial number of the motor. Some motors will not operate satisfactorily if the speed is increased by inserting resistance in the shunt field. In such cases speed variation can be secured by inserting resistance in series with the armature. This will reduce the speed, the output being reduced in proportion to the speed reduction. In this case in ordering a controller the data should be the same as above, except omit 3, 4 and 5 and give the load at which the motor will operate, speed range and character of load. L. D.

620—Fusing Secondary Circuits of Paralleled Distributing Transformers—In the residential parts of a city is it advisable to tie together the secondaries of lighting transformers with either a solid connection or fuse. J. C. H.

The use of fuses on the secondaries of lighting transformers can practically be limited to dividing the secondaries into sections on comparatively large networks for the purpose of localizing disturbances caused by short-circuits. Several transformers can be operated in parallel very satisfactorily with fuses on the primary side only, provided there is a certain length of secondary between the transformers, the resistance of which will act as a ballast to give an even distribution of load. H. N. M.

621—Motor Speed Changed by Shunting Interpole Windings—In an interpole direct-current motor, if the interpole winding is shunted, there will be a change in full-load speed, while the no-load speed will be unaffected. Would you please explain this phenomena? Can the change in speed be ac-

curately calculated from the winding data, the shunt resistance and the saturation curve? L. K.

The normal method of securing speed change in an interpole shunt motor, is by inserting resistance in series with the shunt field winding. If the motor is properly designed and adjusted, the speed change obtained by shunting the interpole winding will be relatively small. If the brushes are not set in the neutral position, a change in the interpole strength caused by shunting the interpole winding, will cause a change in speed, since with the brushes off neutral the armature magnetizing effect no longer directly opposes the interpole magnetizing effect. Shifting the brushes forward or backward on an interpole machine produces the same effect as a similar shifting on a non-interpole machine except that it is more pronounced. The interpole ampere-turns not only oppose the armature ampere-turns, but also set up a field which generates in the coil short-circuited by the brushes an e.m.f. of such magnitude as to overcome the e.m.f. of self-induction in the coil. Shunting the interpole winding has a two-fold effect; it decreases the interpole flux and the saturation in the yoke, and secondly, the interpole flux generates in the short-circuited coil an e.m.f. and current which opposes the main field, acting as a very light reverse compound winding. The change in speed may be estimated, though not accurately calculated, as the amount of change is so slight and there are several variables involved. Shunting the interpole will alter the commutating characteristics, and if carried too far may cause sparking.

L. D.

622—Changing Frequency of Fan Motor—It is desired to change a 133 cycle, 104 volt, 1 200 r.p.m. Holtzer-Cabot single-phase fan motor to operate on 60 cycles at approximately the same speed. The motor has 12 main and 12 starting poles. The rotor has 43 bars. How can this be done?

J. I. T.

This is covered in a general way by the answer to No. 339 in the December, 1909, issue, except that six poles instead of four should be used to obtain the desired speed. Although it would be most advisable to refer the matter to the manufacturers, the following may possibly be of assistance: Rewind the motor for six poles instead of twelve, using the same distribution and connection of the windings as at present, except that ten percent more wires per slot should be used in the main and starting windings than at present. The wire sizes should remain the same as at present, provided it is possible to find room for them in the winding spaces. This should give a speed of approximately 1 100 r.p.m. on a 105 volt, 60 cycle circuit.

H. M. S.

623—Magnetization of Wire Used for Phonograph Needles—A local factory making phonograph needles has had its output materially reduced by the appearance of magnetism in the wire from which the needles are made. The electric company claims that its 550 volt, 60 cycle, three-phase power current driving motors in the factory could not cause this. The proprietors think that it is impossible for their Bessemer steel to arrive in a magnetized condition. It is difficult to prove this, as the steel comes to the factory in coils. Can you suggest the probable source of this magnetism, and some way to overcome it? R. P.

If the steel has been handled by means of an electro-magnet, this might account for the trouble. If the wire is subjected to a hardening process at any time during the manufacture of the needles this would have the effect of eliminating any magnetism on the wire when received. Magnetism in the finished needles might also be due to stray fields—either earth fields or due to neighboring direct-current circuits such as trolley circuits. This magnetism may be removed by passing the needles through an alternating-current magnetic field. It is essential that there be no break in the circuit while the needles are under its influence. An arrangement for doing this would be to pass the needles, by

means of some sort of conveyor, through a fiber or other insulating tube wound with a coil of wire, this coil being connected to the alternating-current supply circuit with a resistor in series to regulate the strength of field. F. C.

624—Three Single-Phase Regulators vs. One Three-Phase Unit— Is it advisable to install three single-phase units to maintain the pressure of our three-phase, three-wire, 2 200 volt bus-bars? It would seem that the attempt at regulation of one of the regulators would affect the other, resulting in very unsteady operation. A three-phase regulator would doubtless be best, but as we have on hand three 300 ampere single-phase regulators, we are considering installing them in the above manner. C. W. S.

The chief advantages of one three-phase regulator over three single-phase regulators are: Lower first cost; less floor space required; fewer parts. A three-phase regulator will not correct for unbalanced phases, whereas with three single-phase regulators, although each will affect the other two, a setting can be obtained by trial which will correct any reasonable unbalancing or variation in voltage. If three single-phase regulators are available and the phases are balanced, it might be desirable to gear the three regulators together and operate them from one hand wheel. The results thus obtained would be practically the same as would be obtained from a three-phase regulator. E. E. L.

625—Portable Current Transformer Used With Sheathed Cable— Given a lead covered cable carrying alternating-current, it is desired to measure current or watts using a portable through type current transformers. If the sheath were of lead and could not be cut and the transformer therefore had to be placed over it, what would be the error: *a*—with the lead covering ungrounded; *b*—if grounded on both sides of the transformer; *c*—if, instead of lead covering, the cable were armoured with iron wire? J. L. S.

The arrangement would be in effect that of a transformer with one primary and two secondary windings represented respectively by the conductor, the transformer winding and the sheath. *a*—With the sheath ungrounded, or grounded at only one point, the sheath would not form a closed circuit and there would consequently be no error introduced in the reading of the meter connected to the current transformer. *b*—If grounded on both sides of the transformer the lead sheath would form a closed secondary circuit in multiple with the secondary winding and an error would be introduced, the magnitude of which would depend upon the cross-section and length, i. e., the resistance, of the lead sheath forming this additional secondary circuit. *c*—Single conductor cable with iron sheath or armor cannot be used for alternating-current service while cables containing both outgoing and return conductors would, of course, have no magnetizing effect if run through a current transformer as assumed in the question; hence this case is not a practical one. H. B. T.

626—Small Commutator Type Alternating-Current Motors— Please give the reasons which prompt a designer to make certain small alternating-current motors, such as for fans, vacuum cleaners, etc., of the commutator instead of the induction type. J. S. A.

The use of alternating-current commutator motors in preference to induction motors is determined by the capacity, size and speed of the motor. For very small capacities it is desirable to keep the diameter as small as possible, and in most cases a series motor can be made smaller than an induction motor. In the case of fan motors it is also desirable to have speed control, which cannot be obtained on induction motors except within very small limits. For vacuum cleaners very high speeds are used in order to reduce the size and weight of the outfit for a given output. With induction motors, a two-pole synchronous speed is the highest speed that can be obtained. On 60 cycles this is 3 600

r.p.m. whereas vacuum cleaners operated by means of series type alternating-current motors commonly run at speeds varying from 5 000 to 7 000 r.p.m. C. A. M. W.

627—Induction Motor Winding Data from Name Plate—Given a three-phase induction motor frame, name plate data and coils for winding, how may the slot span of the coils be determined? Also whether the connection shall be delta or star? J. G. B.

The safe way is to follow the throw of coils and method of connections as determined from the original winding. If this cannot be done, secure the proper information from the motor manufacturer, referring to the serial number of the motor and stating the rating in horse-power, current, voltage, frequency, etc., as shown on the name plate of the machine. R. S. F.

628—Armature Coils—*a*—Do armature coils deteriorate by keeping them on hand? *b*—What is the best way to take care of them when they are to be kept for several months? *c*—How long should an armature be baked after winding, and at what temperature? W. E. C.

a—Armature coils, as usually treated with a linseed oil varnish, will in time become brittle due to the continued oxidation of the varnish. This effect in itself does no harm but makes the insulating material easily damaged in handling. *b*—Keep in some dry place, and if not exposed to the air the material will remain flexible. No serious results will be experienced with coils which are not used within one year. *c*—Ten to 12 hours at a temperature of 200 to 225 degrees F. R. A. M. C.

629—Determination of Secondary Current in Low Voltage Transformer— Please advise the most satisfactory method for determining the current in the low voltage secondary windings of a transformer for electric welding purposes which carries as high as 30 000 amperes. We have found it impractical to use a series transformer to surround the conductor, and would like to know if the values can be calculated from a vector diagram of the primary current with reasonable accuracy. P. C.

If the transformer is of normal design it will be approximately correct to take the secondary full-load current as equal to the primary full-load current multiplied by the ratio

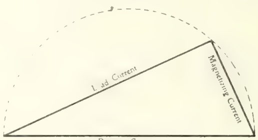

Fig. 629 (a)

of primary to secondary turns. For very low loads this will not be correct, but the simple diagram of Fig. 629 (a) will serve to illustrate the method of obtaining the value of the secondary current. It is equal to the load current in the primary multiplied by the ratio of the primary and secondary turns. C. F.

630—Specifications for Field Rheostats — Please give the exact method of determining the specifications of rheostats for the fields of both alternating-current and direct-current machines. H. G. H.

The function of a field rheostat is to regulate the voltage, speed, or power-factor of a machine. Having given the limits between which the machine is to be regulated, it is first necessary to determine the maximum and minimum shunt field currents. Alternating-current machines and direct-current motors are ordinarily excited from a constant voltage, so that the exciting voltage divided by the minimum field current gives the total resistance required in the field circuit. Subtracting from this value the resistance of the field gives the resistance required in the rheostat. The maximum current is obtained by dividing the exciting voltage by the field resistance. Direct-current generator rheostats are figured in a similar manner, except that the exciting voltage changes and the minimum or maximum voltage corresponding to minimum or maximum field current is used instead of a constant exciting voltage. The number of steps, and resistance per step, depends on the kind of regulation to be secured. H. C. N.

THE
ELECTRIC JOURNAL

Vol. VIII NOVEMBER, 1911 No. 11

Electric Locomotives for Mines

In the early development of mines and until comparatively recent years, little thought was given to the heavy traffic through the entries as the mines were developed and extended. As a rule, animal haulage was adopted and tracks were laid on the basis that the loaded cars would be the heaviest equipment to be carried.

When the workings of the mines became remote from the point of delivery of the product, and with the successful development of electric locomotives, rapid progress was made in the introduction of such locomotives as a substitute for animal haulage, Where the track construction was comparatively light, owing to the initial conditions, small locomotives were necessarily employed. In many instances, however, the traffic conditions were heavy enough to justify re-laying the tracks for a more economic transportation system using heavier locomotives. In a large majority of cases the gauges were narrow and the result was that the motor equipment was necessarily more restricted on account of space limitations than, for example, in the case of street railway equipments. For this reason extreme care had to be exercised in regard to the handling of the equipment, and the earlier locomotives were supplied with motors of relatively small capacity, ranging from as low as five horse-power per ton weight of locomotive to a possible maximum of eight horse-power per ton, based upon speeds of six to seven miles per hour.

At the present time, unless the territory is known to be extremely gaseous, no coal mine is laid out without due consideration of electric haulage, and furthermore, in the transformation of the older mines it is now realized that competition in the production of coal demands the most economic haulage system available. As a result nearly all operators are willing to lay track sufficiently heavy to take care of the motive power equipment best suited to the conditions.

It has been demonstrated that there is no safe rule to adopt in regard to horse-power per ton of locomotive equipment, but that

it is preferable to secure all possible information in regard to the conditions to be met, in the same manner that the service conditions are figured for street railway equipment; and the proper equipments, based on up-to-date ideas and methods, should be selected to suit the local conditions. Due appreciation of this situation has not been generally shown by the mining trade, but they are now rapidly recognizing the necessity of engineering in laying out their haulage systems.

The article by Mr. Graham Bright in this issue of the JOURNAL is, therefore, timely and should be of great assistance in dealing with problems of this character. It indicates forcibly the advantages, both to the user and the manufacturer of electric mine locomotives, of a full knowledge on the part of the prospective user as to the basis upon which the locomotive equipments are legitimately determined.

W. A. THOMAS

Addresses to Engineering Students

It is well now and then to get a good perspective view of our surroundings, to climb a high hill or a mountain peak and look over the plain or valley in which we live, in order to see where we are with reference to other people, to observe how our interests are related to theirs, and to find whether our attitude, our efforts and our ideals are in proper accord with the world about us. Rising out of the general level of technical matters, of windings and calculations, of power transmission and motor drive, of prime movers and efficient operation, there have now and then been articles in the JOURNAL which rise like high peaks upon which one may climb and get a broader view, a refreshing breath and a new inspiration. In one of the very early issues was that strong article by Mr. Frenyear on "Man Power." What keen insight he gives us into the philosophy of life; how well he analyzes the elements which give power to the individual and lead to the true principle in the management of men; "getting others to do what you want done while they themselves are doing what they themselves wish to do. Inspiring others with a desire to do what you want done, not driving them to do it. Knowing men, setting before them the objects of their ambition and affection in the line of your own purposes."

There is a general tendency among engineers to do the smaller, lesser thing, to get so close to details that one cannot see beyond, or to be so absorbed in pure engineering that its larger relations to life are obscured.

Youth is the time for large vision and high ideals. And yet the editors of "Addresses to Engineering Students" say that most young men who enter the engineering courses of technical schools do so because their parents desire them to receive a useful education or because they think engineering a good calling in which to make a living, while "very few enter on account of a heartfelt admiration of engineering as the profession of progress, to which is due practically all of the wonderful developments of the last one hundred years—developments that have so added to the comforts and conveniences of man as to make life truly worth living instead of a burden grievous to be borne." To give the true point of vision they have brought together in one volume some forty addresses to students by educators and engineers.

It is interesting to note how many of these addresses have appeared in the JOURNAL, such as "The Durable Satisfactions of Life," by President Eliot; "Business Training for the Engineer," by President Humphreys; "Some Relations of the Engineer to Society," by Col. H. G. Prout; "The Point of View," by Mr. Walter C. Kerr, and "Study Men," by Mr. Hayford. This is sufficient assurance to the JOURNAL readers that this collection of addresses, directed primarily to the engineering student in college, is of prime interest to the students of later years who seek the inspiration which such addresses give to those who belong to the profession of progress.

The editors of "Addresses to Engineering Students", Messrs. Waddell and Harrington, consulting engineers of Kansas City, Mo., have contributed of their time and effort and money in order that this notable book, which would ordinarily command several dollars, may be sold for one. They have done a notable service to the engineering student and to the engineering profession.

CHAS. F. SCOTT

Friction Loss at Full Load

The time honored method for determining the friction loss in a line shaft, is to take off all the belts from the line shaft to individual machines or counter-shafts and indicate the engine. The difference between the full load on the engine, and the value of friction loss thus obtained has been assumed to be useful work. While it has been generally understood that the friction loss is greater at full load than at light load, no ready means has been available

for accurately determining how much greater it has been, and the error involved has been neglected. Owing to the close competition between the various methods of drive for factory machinery, analyses of operating conditions are being made more carefully than has been customary in the past. The article by Mr. Popcke, in the present issue of the JOURNAL, includes a method by means of which the full-load friction loss may be measured with an accuracy which is well within commercial requirements for work of this type. This method is based on the assumption that the full-load plus the friction loss can be measured, either by an indicator, or by electrical methods, and that if certain sections of the load be cut off by clutches, throwing off of belts or other similar method, and the remaining load measured, the difference will represent the power consumed in the section cut off. The difference between the power used in the various sections, and the total power used equals the full load friction loss. The error consists in assuming that the friction loss in the transmitting belts and shafting remains the same before and after a section of the load is removed. This error is comparatively small, however, if a sufficient number of sections are chosen, and is also in a conservative direction, i.e., it tends to make the calculated value of the friction loss less than the actual. If greater accuracy of method is desired, this error can be calculated by assuming that it bears the same ratio to the difference between no-load friction and full-load friction that the average power required for each of the sections does to the total amount of power.

Another variable source of error lies in the fact that if indicator cards must be taken, the load is liable to vary between readings. In a large plant, such as that tested by Mr. Popcke, the error from this source will probably be small as, owing to the large number of machines in operation, the load remains fairly constant. In fact, readings as given in one of the tables show that the total load varied by an amount not much greater than the accuracy of an indicator mechanism with its subsequent planimeter readings.

It would have been possible in this particular plant to further sub-divide the load by throwing off belts from the machines on a section of each floor, and thus obtain also the friction loss of the line shafting on each floor at full-load. If too great a subdivision is made, however, the differences become so small a proportion of the total load that a very slight error in the measurement of the

latter will make a very large error in the resulting figures for friction loss. This difficulty could be overcome by inserting a transmission dynamometer or electric motor and reading the total load on the floor or section by this means, but it is doubtful if, in the majority of cases, the information secured would be worth the expense of such a test, if the test involves also a loss of production.

The plant which was the subject of this particular test was especially well arranged for such a purpose in that each floor could be disconnected separately by means of a clutch. The method is, however, applicable to any shop where the load can be kept approximately constant.

In another respect also, Mr. Popcke's methods of calculation are to be emulated. While admittedly arguing in favor of individual drive, he nevertheless concedes to the other methods every possible advantage. Calculating the no-load losses for an individual drive is undoubtedly unique. Moreover the no-load losses in the motors for the group drive have been neglected, although in this case the motor is operating at nearly half load and a direct comparison is made between the two cases. It is evident that Mr. Popcke believes that if an advantage can be shown in spite of this and other handicaps, the argument is so much the stronger. The advisability of a conservative attitude in submitting a commercial report admits of no argument. If a saving of twenty-five percent has been promised as the result of a change in method of drive, and a larger saving is actually secured, no ill feelings follow, but a reversal of this condition is sure to result in a distrust of any future reports from the same source. CHAS. R. RIKER

PARALLEL OPERATION OF COMPOUND-WOUND GENERATORS

C. I. YOUNG

TWO compound-wound generators may, in general, be run in parallel by shunting the series fields of either one or both of them in such a way as to secure the same no-load and same full-load voltages. But in such cases it is often found impossible to maintain the balance in load between the machines without frequent adjustment of their shunt field rheostats. It is obviously desirable that satisfactory adjustments should be made at the time of erection so that a minimum amount of attention will be required in operation.

The factors to take into account for parallel operation of two over-compounded direct-current generators are:—

1—The desired rate of over-compounding and its relation to the generator capacity.

2—The resistance of the series field and its shunt.

3—The resistance of the cable between the series field and the bus-bar; also the resistance of the bus-bar between the points where the series fields of the two machines are connected.

4—The shape of the e.m.f. regulation curves of the two machines.

5—The resistance of the equalizer.

The Rate of Over-compounding is the measure of increase in e.m.f. from no load to full load, due mainly to the series field winding. It may be expressed in terms of *volts rise per ampere output of generator,* and designated by the letter K. For example, assume a no-load voltage of 230 and full-load voltage 240, the rise in voltage is 10. For a generator whose full-load current is 100 amperes, K will be $10 \div 100 = 0.1$.

Where two generators A and B are of different capacities, the load should be divided between them in proportion to their capacities; therefore each machine should over-compound at a rate inversely proportional to its capacity.

Assume a no-load voltage of 230 and a full-load voltage of 240. Let the full-load current of A be 600 amperes and that of B, 800 amperes. With a load of 600 amperes, A should over-compound ten volts, or $K = 0.0167$. Likewise B should over-com-

pound ten volts with 800 amperes, or $K = 0.0125$. Ordinarily the series fields of compound-wound machines are designed to give the maximum increase in voltage which they are likely to be called upon to furnish. It is generally necessary to shunt these fields by resistances in order to reduce their compounding to the desired amount. The amount of over-compounding varies with the current that passes through the series field winding; this variation would be in proportion to the current were it not for variations in the strength of the shunt field due to rise or fall in voltage, variations in speed of rotation due to change in load, and also the fact that the strength of a magnetic field does not vary in direct proportion to the exciting current. Characteristic curves, plotted from simultaneous readings on a 150 kw, 250 volt, direct-current engine type generator without a shunt on the series field, are given in Fig. 1. From no-load to full-load (600 amperes) the machine over-compounds from 230 to 250 volts, and $K = 20 \div 600 = 0.0333$. This, however, is only the average rate. Taking successive steps it may be seen that from 0 to 100 amperes the voltage rises from 230 to about 237.5, and $K = 0.075$; from 100 to 200 amperes, $K = 0.071$; from 600 to 700 amperes $K = 0.01$. This characteristic will be referred to later as it has a direct and important bearing on the division of load between compound-wound generators.

RESISTANCE OF THE SHUNT

In making the first determination of the amount of resistance required in parallel with the series field, the method is as follows:—

Assume that generator *A*, Fig. 2, is running alone with no shunt on the series field, and that it over-compounds from 230 to 250 volts from no-load to full-load of 600 amperes. It has 882 turns per coil in the shunt field and eight turns per coil in the series field. The resistance of the series field is 0.00316 ohms, and the curve for shunt field amperes combined with the regulation curve shows that the resistance of the shunt field plus the rheostat section necessary to give 230 volts at no-load is 34.1 ohms.

It is desired to run the machine at 245 volts at full-load without change in the no-load voltage; that is, to reduce an over-compounding of 20 volts to 15 volts by means of a shunt on the series field. From the saturation curve, Fig. 1, it is seen that with the shunt field alone, at full load, 12.3 field amperes are required to produce 245 volts. This means that the total ampere-turns re-

quired to produce 245 volts at full-load equals $12.3 \times 882 = 10\,850$. However, at 245 volts, with the rheostat setting correct for 230 volts at no load, the shunt field current, as read from the curve, or as calculated $(245 \div 34.1) = 7.19$ amperes. The shunt ampere-turns equal $7.19 \times 882 = 6\,330$ and the series field must evidently furnish 4 520 ampere-turns to make the requisite total of 10 850. The current in the series field must therefore equal the ampere-turns (4 520) divided by the series turns (8) = 565 amperes. The series field shunt must then carry 35 amperes, and its resistance must equal $565 \div 35$ or 16.1 times that of the series field, i.e., $16.1 \times 0.00316 = 0.052$ ohms.

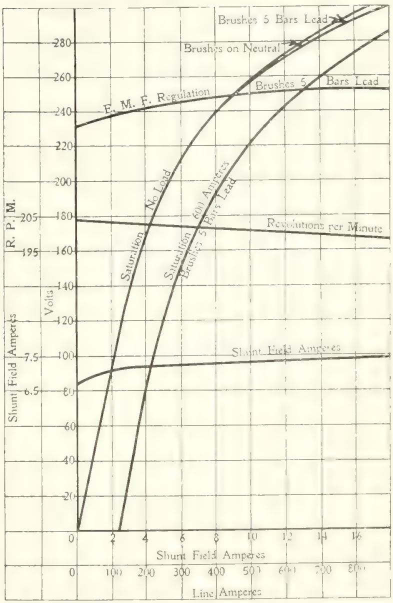

FIG. 1—REGULATION AND SATURATION CURVES OF 600 AMPERE 250 VOLT 200 R.P.M. ENGINE-TYPE GENERATOR

A more usual condition is the case of a generator that has already been supplied with a shunt for the series field, but still over-compounds too much. In this case it is much more convenient to consider the combined series field and shunt resistance as a unit, in which case the resistance of the new shunt can be found in ohms, or in terms of the combined resistance, by the method previously outlined. This new resistance can then be added in parallel to the other shunt. The same result can likewise be secured by putting a resistance in series with the series coil, S_a, inside its connection with R_a. This will send a greater proportion of the total current through R_a, thus decreasing the compounding, and will also slightly increase the resistance of the total circuit. In case the compounding is to be increased, the old shunt will have

to be replaced by one of higher resistance, or an additional resistance may be placed in series with R_a inside its connection with S_a. It is thus frequently unnecessary to determine the resistance of the series field and its shunt, separately. When this is necessary, the circuit of either the series field or its shunt will have to be opened and the resistance of the other measured independently.

COMPARATIVE RESISTANCE OF THE CIRCUITS

The next point is the determination of the relative resistance of the series field circuits of the two machines. Assume, for the present, that the resistance of the equalizer is zero. It will be seen that the circuits to be compared in Fig. 2 do not consist merely of the series fields with their shunt resistance, but include cables and bus-bars; it is therefore necessary that the resistance of $AA'B'$ be compared with BB' and that these resistances be inversely proportional to the capacities of the machines. Where this proportion does not exist the proper amount of series resistance may be inserted in the cable between the series field of one machine and the bus-bar.

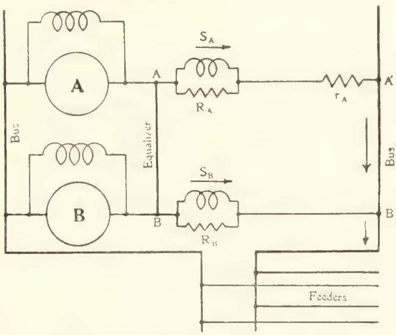

FIG. 2—DIAGRAM OF CONNECTIONS FOR TWO COMPOUND-WOUND GENERATORS IN PARALLEL

If the resistance of the series field circuit $AA'B'$ is correctly proportioned to BB' for the proper division of load, and a shunt R_a is placed across S_a, the resistance of $AA'B'$ is reduced and the proportion changed. To bring it back to its original value, a resistance r_a must be inserted equal to the difference between the resistance of the series field, and the combined resistance of the field and its shunt. Then $r_a = S_a - \dfrac{1}{\dfrac{1}{S_a} + \dfrac{1}{R_a}}$, which can be solved directly in ohms, or by assuming $S_a = 1$, and R_a in terms of

S_a, r_a can be solved in percentages. Thus, in the case assumed $r_a = (1 - \frac{1}{1+\frac{1}{16.1}})\, S_a = \frac{1}{17.1} \times S_a$.

For example, assume, in the case cited above,

Cable and bus = 0.002 ohms = 200 ft. of 1 000 000 C. M. cable
S_a = 0.00316 ohms

Then AA'B' = 0.00516 ohms
Inserting R_a = 0.052 ohms in shunt with S_a,

$$R_a \ \&\ S_a \text{ in parallel} = \frac{1}{\frac{1}{0.00316} + \frac{1}{0.052}} = 0.00298 \text{ ohms}$$

Cable and bus	=	0.00200 ohms
r_a	$= \frac{1}{17.1} S_a$	= 0.00018 ohms
	AA'B'	= 0.00516 ohms

Paralleling the series field by a shunt resistance, always reduces the compounding of a machine. But occasionally the condition arises where the compounding must not be changed, but still the machines do not run properly in parallel. In such a case, with machines of similar characteristics, the desired results may be obtained by inserting a resistance in the main lead of the machine which is giving excess current, its value being such that the resistance of the machine circuits will become inversely proportional to their capacities.

It is, of course, impossible to raise the compounding of a machine by any current of its own, beyond that produced by its maximum series field. When paralleled with a machine of higher compounding characteristics, however, it is possible to make the busbar voltage higher than that produced by the lower voltage machine operating alone. This is done by sending part of the current from the one machine through the series field of the other. For instance, assume that machine *A* over-compounds 20 volts at full load of 400 amperes and that machine *B* over-compounds ten volts at full load of 800 amperes and that both machines flat compound with half full-load current in the series field. The resistance of the field and leads of both machines is the same and equal to 0.1ohm. It is desired to have the machines divide the load equally at maximum over-compounding.

For a short cut method, in case the saturation curves of the two machines are not available, knowing the current necessary in the series field to produce flat compounding, and the voltage rise produced by full-load current, it may be assumed that between these

values the voltage rise is proportional to the current rise. Under the conditions assumed, with negligible equalizer resistance the machines would tend to divide the load as follows:—

Machine A has a voltage rise of 0.1 volts per ampere in the series field, starting with 200 amperes in the series field and full load in the armature, while machine B has a rise of 0.025 volts per ampere, starting with 400 amperes in the series field and full load on the armature. This leaves 600 amperes to be divided between the two machines so as to produce equal voltages and maximum compounding. Manifestly $\frac{0.1}{0.125}$ of 600 or 480 amperes should go through the field of machine B and $\frac{0.025}{0.125}$ of 600 or 120 amperes through the field of machine A. This will produce a rise above flat compounding of 12 volts in each machine. Machine A then carries 200 + 120 or 320 amperes and B carries 400 + 480 = 880 amperes. The resistances of the two circuits must vary in inverse proportion to the current. As the resistance of B cannot be decreased, A must then be made to equal $\frac{880}{320}$ of 0.1 = 0.275 ohms, i.e., a resistance of 0.175 ohms must be added to this circuit. More exact results may, of course, be obtained if the saturation curves of the machines are obtainable, but the above method gives a good approximation.*

While actual values in ohms have been used in the discussion on the resistance of the series field, its shunt, cables, etc., the knowledge of *relative* values rather than *actual* values is all that is required. Referring to Fig. 2, if S_a is to carry 75 percent of the output of generator A, R_a must have three times the resistance of S_a, whatever that resistance may be. If generator B has twice the capacity of A, the series field circuit of A, which is $AA'B'$, must have twice the resistance of BB'. (In this connection note that the selection of B' as the junction common to both has been determined by the position of the feeders on the bus-bars. Had the feeders been above A', that point would have been the common junction, and in that case AA' should have twice the resistance of $BB'A'$ to satisfy the conditions just cited).

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*For description of an extreme case of this kind which was satisfactorily solved by the method outlined, see article by Mr. H. L. Beach, in the JOURNAL for November, 1909, p. 683.

The use of a millivoltmeter offers a practical method for determining the relative values of resistances. For example; if a shunt is required having a resistance three times that of the series field winding, connect the german silver strips, from which the shunt is to be made, in series with the field; put on a load, with ammeter in circuit to determine when the current is constant and, by means of the millivoltmeter, find a length of the german silver strip that will give a drop three times that found across the terminals of the series field. The resistance in ohms can be calculated from the values secured, but is not necessary.

If the station load is not suitable for test purposes, the generator may be run at a very low voltage, i.e., in a very weak field, and short-circuited through the series field, german silver strip, circuit breaker and ammeter. The suggested arrangement is shown in Fig. 3, where *A* is the armature, *ef* the shunt field in series with a high resistance rheostat *R*, and shunted if necessary by a second rheostat *R'*; *ab* is the series field and *bc* the german silver strip. Comparative drops are taken across *ab* and *bx*. It is not impossible that the test may be made with the shunt field open, using the series field only. The current may be kept down, if necessary, by the insertion of additional resistance or by reduction of the engine speed.

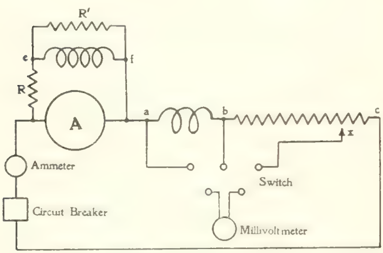

FIG. 3—CONNECTIONS TO OBTAIN FULL-LOAD CURRENT AT VERY LOW VOLTAGE

A comparison of the resistance of the series fields or of the generator leads, as for instance, *AA'B'* with *BB'*, Fig. 1, can be made by a similar test. Preferably the same ammeter should be used in the two tests, and also as nearly as possible, the same load. If different ammeters are used they should first be compared in order to find the corrective factor to apply when comparing readings. In view of the fact that copper and german silver have widely different temperature coefficients it is better to make the above measurements after the generators have been operating under full load for some time.

THE REGULATION CURVE

With the shunts on the series fields of the two machines adjusted to give the same over-compounding between no-load and full-load and with the respective resistance of their series field circuits proportioned so the load will be properly divided, there is another condition, which may possibly give trouble. Referring again to the regulation curve, Fig. 1, it may be seen that from 0 to 100 amperes, $K = 0.075$; from 200 to 300 amperes, $K = 0.054$. The slope of the curve continually grows less, until between 600 and 700 amperes, $K = 0.01$.

In Fig. 4 two theoretical regulation curves, A and B, are shown each illustrating an over-compounding from 230 to 240 volts at 600 amperes. As has been shown, this adjustment can be made by properly proportioning the shunts on the series fields. But here it will be noted that for loads below 600 amperes A is at a higher voltage and will therefore (if there be no change in the conditions) take a greater proportion of the load. Similarly for loads above 600 amperes B will take a greater proportion. Since the voltage of a generator varies as the product of field strength and speed it is sometimes possible to meet a situation like this by a change in speed of the prime mover. For example, in this case the prime mover of A could be speeded up, involving operation in a weaker field farther down on the saturation curve, which would bring its regulation curve more nearly in line with that of B. Conversely the prime mover of B might have its speed reduced forcing it to operate in a stronger field higher up on the saturation curve which would bring it more closely in line with A. Before this is tried the regulation curve of each machine should be determined separately from a set of four to six or more readings both from no-load up to full-load, and back again from full-load to no-load. The adjustment of engine speed should not be attempted by anyone who is unfamiliar with the engine. A slight change in speed of either prime mover is generally all that is required.

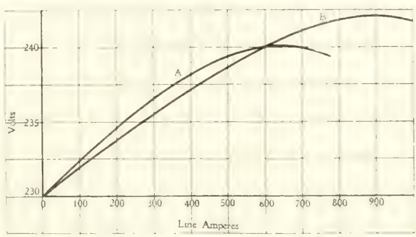

FIG. 4—REGULATION CURVES FOR MACHINES OF VARYING CHARACTERISTICS BUT SAME NO-LOAD AND FULL-LOAD VOLTAGE

THE EQUALIZER

In Fig. 2, the equalizer is shown between A and B. This connection is essential for the successful parallel operation of two or more compound-wound generators, as without it the combination would be electrically in unstable equilibrium.

The operation of the equalizer is so simple that this important factor in successful operation does not always receive the attention it merits. It is desirable, first, that machines in parallel operate as nearly as possible at the same voltage, and second, that the load be divided between them in proportion to their respective capacities at all times. The equalizer carries a corrective current from one machine to the other, the tendency of which is to produce the above two conditions. The current in the equalizer varies directly with the difference in voltage between the two machines and inversely with its resistance; the greater this resistance, the greater the difference in voltage required between machines to produce a given corrective current.

Assume that, in Fig. 2, the capacity of A is 600 amperes, the capacity of B is 800 amperes, and that the resistances of the circuits are inversely proportional to the capacities and the characteristics of the machines are similar. Suppose the shunt field of machine B is raised until B carries 1 100 amperes and A but 300. With zero equalizer resistance, $AA'B'$ would still carry 600 amperes and BB' 800, the equalizer carrying 300 amperes, and the compounding would be practically the same, and the unbalanced load would remain practically constant.

Assume the resistance of $AA'B' = 0.008$ ohms, $BB' = 0.006$ and the equalizer $AB = 0.002$ ohms. The current of machine A will have two paths $AA'B'$ and ABB' in parallel, each equal to 0.008 ohms, and will divide equally, 150 amperes in each branch. The current of B, 1 100 amperes, will also have two paths, $BB' =$ 0.006 ohms and $BAA'B' = 0.010$ ohms, and the current will divide in inverse proportion, i.e., 687.5 and 412.5 amperes. This will make the total current in $AA'B' = 562.5$ and in $BB' = 837.5$, while the equalizer will carry 262.5 amperes.* The current in AA' is thus 37.5 amperes less and that in BB' is 37.5 amperes more than normal. If S_a has eight turns on the series field and S_b has six turns, this would cause a difference of 525 ampere-turns between the fields of the two machines, in addition to that already existing on account of the difference in shunt fields, causing a further rise in

*See footnote, page 983.

voltage of *B* and a corresponding drop in the voltage of *A*, thus resulting in a still greater disparity in current outputs. The point of final stability will depend on the characteristics of the two machines, as this tendency is to a certain extent counterbalanced by the fact that with increasing loads a machine operates at higher saturation and, as shown by the regulation curve, Fig. 1, its compounding coefficient *K* grows less as the voltage itself increases. Again there is a further counter-balance in the falling speed characteristic of most prime movers with increasing load.

As in the cases of resistance in a series field circuit, so in the case of equalizer resistances, the question is one of *relative* resistance only. Its resistance must be low as compared with the sum of the resistances of the two series field circuits. A good general rule to follow is to use the same size cable for the equalizer as for the positive and negative cables, and to run the equalizer by the shortest path between machines.

Where the generators are of interpole construction the interpole winding must invariably be considered as a part of the armature and the equalizer must be connected between the interpole winding and the series field, never between the armature and the interpole winding.

*This may be expressed by a formula as follows:—

Let $V =$ volts drop over *BA* (Fig. 2), $r =$ resistance of *BA*, $R_a =$ resistance *AA'B'*, $R_b =$ resistance *BB'*, $R_o = r + R_a + R_b$, $X =$ current in equalizer, (*BA*), $I_b =$ output of machine *B* at the given rheostat setting, $I_a =$ output of machine *A*, $I_b - X =$ current in *BB'*, $I_a - X =$ current in *ABB'*.

$$\text{Then,}\qquad (I_b - X)R_b = V + (I_a + X)R_a \quad \text{or} \quad I_b - X = \frac{V}{R_b} + (I_a + X)\frac{R_a}{R_b}$$

$$\text{Now,}\qquad X = \frac{V}{r} \qquad \therefore \qquad I_b - \frac{I_aR_a}{R_b} = \frac{V}{r} + \frac{V}{R_b} + \frac{VR_a}{rR_b}$$

$$\text{Hence,}\qquad V = \frac{I_b - I_a\dfrac{R_a}{R_b}}{\dfrac{1}{r} + \dfrac{1}{R_b} + \dfrac{R_a}{rR_b}} = \frac{I_b - I_a\dfrac{R_a}{R_b}}{\dfrac{r + R_b + R_a}{rR_b}} = \frac{I_brR_b - I_arR_a}{r + R_b + R_a} = r\,\frac{I_bR_b - I_aR_a}{R_o}$$

$$\text{Amperes in Equalizer} = X = \frac{V}{r} = \frac{I_bR_b - I_aR_a}{R_o}$$

This formula is based on the assumption that the voltage is higher in machine *B*. If *A* is at a higher voltage, the value of *X* will be negative, indicating that the current flows from *A* to *B*.

ROTARY CONVERTERS

The operation of rotary converters in parallel presents conditions that are somewhat different from those for generators:

1—The direct-current voltage is not affected so directly by the current in the series field winding as in the case of a compound-wound generator.

2—Its speed cannot be adjusted since it is fixed by the frequency of the supply circuit and the number of poles in the rotary.

Compounding of a rotary is the resultant of three factors—

a—The strength of the field.

b—The inductance of the transformer winding to which the converter is connected and of the cables between transformers and converter.

c—The resistance and reactance of the alternating-current transmission circuit from which power is received.

Leaving out the question of split-pole, and booster rotary converters and considering only the standard commercial compound-wound rotary converter, the direct-current voltage has a ratio to the alternating-current voltage which is practically fixed. A converter operating in a weak field takes a comparatively large lagging current which grows less as the field is strengthened and may become a leading current in a very strong field. If inductance be introduced into the alternating-current circuit supplying power to the converter and it be run with a weak field at light load, the power-factor of the alternating-current supply circuit will be low. As the load increases the field of the converter is strengthened by the increased current through its series field winding and the power-factor is raised, the tendency being to maintain more uniform drop in the supply circuit resulting in a more nearly constant alternating-current voltage at the rotary converter terminals. In adjusting the connections of two converters for parallel operation, the placing of a shunt across the terminals of the series field is less likely to be required than in the case of a direct-current generator. Where this is done it is for the purpose of securing desired power-factors at no-load and at full-load.

As in the case of two direct-current generators, for ideal conditions the resistances of the series field circuits of two rotaries should be inversely proportional to their capacities, and the equalizer should be of low resistance as compared with the sum of the resistance of the series field circuits. However, the alternating-current connections between the rotaries in parallel act, to a certain extent, like the equalizer lead, so that it is not absolutely necessary to have a

low resistance equalizer. In fact, in rare instances, compound-wound rotary converters have been operated in parallel without any equalizer. This, however, is not good practice.

SUMMARY

To review the situation:— It is a good plan to take a regulation curve on a generator after it has been connected to the prime mover with which it is to operate. The regulation curve furnished with a machine, though a correct record of test, may not give the opperating characteristics in service, for the reason that the shape of this curve will depend to some extent on the speed regulation of the prime mover.

After determining the regulation curve the next point is the consideration of the shunt resistance for the series field and the resistance to be connected between the series field and the bus-bar. In the majority of cases this is all that will be required. However, if after these adjustments the machines still fail to divide the load in proportion to their capacities, it is in order to investigate the shapes of their regulation curves and see if some slight adjustment in the speed of either of the two prime movers, or perhaps both of them, cannot be made, such as will bring their curves more nearly in line. This can readily be done with belt driven machines or with machines connected to direct-current motors, reciprocating steam engines or steam turbines, in any but exceptional cases. With water wheels or gas engines, adjustment is not so easy. With induction motors the proposition is difficult; it is possible to secure slightly lower speeds by sloting the end rings to increase their resistance, but higher speeds are practically impossible.

If the adjustment of the shunt on the series field, and the series resistance between the series field and the bus-bar is well made for each machine, and the regulation curves are lined up closely, the equalizer will have comparatively small corrective current to carry. But in many cases the generators are driven by prime movers, where speed adjustment is difficult or impossible. In such cases it may be necessary to put in an equalizer of larger size than the positive and negative cables between the machines. If the machines still refuse to divide the load properly it is possible to help matters by inserting additional resistances in the series field circuits of both machines (the ratio of resistance of these two circuits being maintained), which will have the effect of making the ratio of equalizer resistance to the series field resistance lower and improving the operation, but at the expense of economy.

WEIGHT AND EQUIPMENT OF MINE LOCOMOTIVES

THEIR DETERMINATION IN PRACTICE

GRAHAM BRIGHT

IN selecting a locomotive to meet a certain set of conditions in a mine or industrial operation the first thing to determine is the weight necessary to give the proper characteristics in regard to running and starting draw-bar pull and braking. The electrical equipment suitable for the operating conditions can then be selected.

WEIGHT

The determination of the weight of a locomotive for mining or industrial purposes is a comparatively simple matter and depends on the loads to be handled, the frictional resistance, the length, value and directions of the grades, the rate of acceleration, the kind of wheels used, and the weight of rail.

An actual test should always be made in connection with any given project in order to determine the exact frictional resistance of the cars. On straight level track it is not safe to figure in preliminary calculations on less than 30 pounds per ton for frictional resistance of trailing cars, unless actual tests show that a lower figure can be used. New cars will often show much less than 30 pounds per ton, but if not well maintained, as is sometimes the case, as they grow older the resistance may be as high as 30 pounds per ton or higher. A resistance of 15 pounds per ton is common for locomotives, although in some cases it is found to be as low as 12 pounds or less. Under ordinary conditions the locomotive resistance is a very small percentage of the total tractive effort, and a change of several pounds in either direction will not materially affect the weight of the locomotive, and will affect the capacity of the motors to a small extent only. A change in the frictional resistance of the trailing load, however, will have a much greater effect on both the locomotive weight and motor capacity.

When a locomotive or car is operating on straight level track, the draw-bar pull available for hauling a trailing load (provided sufficient tractive effort is available in the motor equipment) is limited only by the adhesion that can be obtained between driving wheels and rails, as long as only a low rate of acceleration is in-

volved. For mine operation an acceleration of not more than 0.2 mile per hour per second is sufficient. This will increase the tractive effort about 20 pounds per ton, including weight of both trailing load and locomotive. If there are no grades, the extra tractive effort required for acceleration is a larger percentage of the total than when grades are involved. A heavier locomotive will be required if a high rate of acceleration is used. If, however, as in the large majority of cases, grades up to five or six percent exist, on which it is seldom necessary to accelerate at full load, then the percentage of increase in weight of locomotive demanded due to acceleration will be so small that it is no longer a controlling factor. Accordingly, with the low accelerations common to ordinary mine and industrial work, this factor is considered as negligible in view of the greater percentage of adhesion obtained for starting than for running conditions.

It has been found in practice that, with cast iron wheels a running draw-bar pull equivalent to an adhesion of 20 percent of the weight on the driving wheels can be obtained with clean dry rails on level track without the use of sand. A steel tired wheel seems to obtain a better grip on the rail, and a draw-bar pull equivalent to an adhesion of 25 percent can be obtained under the same conditions. When starting heavy trains and when on steep grades, it is permissible to use sand, in which case a draw-bar pull equivalent to an adhesion of 25 to 30 percent for cast iron wheels and 30 to 33 1/3 percent for steel tired wheels can be expected. This allows extra adhesion for starting the trips. Values as high as 40 to 45 percent have been obtained under exceptionally good conditions of operation, including the use of sand. However, such high percentages should not be counted on in practice, as a very liberal use of sand on both rails is necessary, and the use of too much sand should not be encouraged, since it tends to work into the bearings and gears.

Where no grades exist the weight of the locomotive should, therefore, be five times the draw-bar pull for cast iron wheels, and four times for steel tired wheels, unless the rate of acceleration is such that additional weight is required. When, however, a locomotive with trailing load is ascending a grade the draw-bar pull is necessarily greater than that required to overcome friction of trailing load, as the weight of this load has to be lifted up the grade. For every one percent grade 20 pounds per ton should be added to

often difficult to determine the capacity in the same manner as the draw-bar pull required on straight level track, since 20 is one percent of 2 000.

The effect of the grade on the locomotive as well as on the load must be considered. On a grade, a locomotive cannot exert a draw-bar pull as great as on the level. This becomes very evident when an abnormal grade is considered on which a locomotive will barely be able to propel itself and if any trailing load be added the wheels will slip. The greater tendency for the wheels to slip on a grade is due to the increased tractive effort necessary to propel the locomotive itself, and the weight transfer due to the grade.

Since the weight of a locomotive must be known before the added tractive effort of the locomotive due to grade can be figured, it is best to use a formula to calculate the weight, although it can readily be determined in two or three trials. The formula is, however, so simple that it is usually employed in order to save time.

On the level with cast iron wheels, $W = 5 \times FA \div 2\,000 = FA \div 400$.

With steel tired wheels, $W = 4 \times FA \div 2\,000 = FA \div 500$.

On a grade, with cast iron wheels, $FA + 20 \times G \times A + 20 \times G \times W = 400W$.

With steel tired wheel, $FA + 20 \times G \times A + 20 \times G \times W = 500\ W$, where, W = Weight of locomotive in tons; A = Weight of trailing load in tons; G = Grade in percent; F = Frictional resistance of cars per ton.

In these equations the term FA is the draw-bar pull on level track; $20 \times G \times A$ is added draw-bar pull of trailing load due to grade; $20 \times G \times W$ is the added attractive effort of locomotive due to grade, and $400W$ and $500W$ represent 20 percent and 25 percent adhesion for cast iron and steel tired wheels respectively.

The application of these equations can be better understood by considering an actual example. Assume a trip of 20 cars weighing four tons each including load, or a total trailing load of 80 tons, the frictional resistance of the cars being 30 lbs. per ton.

Then, on level $W = \frac{30A}{400} = \frac{3}{40} \times 80 = 6$ tons for cast iron wheels; $W = \frac{30A}{500} = \frac{3}{50} \times 80 = 4.8$ tons for steel wheels. On one percent grade, with cast iron wheels, $30 \times 80 + 20 \times 80 + 20W = 400W$, or, $W = 10.5$ tons, and with steel wheels, $30 \times 80 + 20 \times 80 + 20W = 500W$, or, $W = 8.35$ tons. On three percent grade, with cast iron wheels, $30 \times 80 + 20 \times 3 \times 80 + 20 \times 3 \times W = 400W$, or, $W = 21.2$ tons, and, with steel wheels, $30 \times 80 + 20 \times 3 \times 80 + 20 \times 3 \times W = 500W$, or, $W = 16.3$ tons.

The above figures show a decided advantage for steel tired wheels over cast iron; the former are more expensive and require a little more vertical track clearance, but the extra cost is more than offset by the lower cost and saving in power of the lighter locomotive. With steel tired wheels the tires can be turned once or twice and then a new tire shrunk on without disturbing the center. It may also be readily seen from this example that the grade conditions are a large determining factor in figuring the weight of a locomotive. For this reason the value and length of the grades should be determined as accurately as possible and also the length of the cars. Mine cars are from seven to ten feet long, and accordingly a trip of 50 or 60 cars will be from 400 to 600 feet long; thus, if a severe grade is only 200 or 300 feet in length, only a part of the trip will be on the grade at one time, and consequently a much lighter locomotive may be used than if the length of the grade were equal to or greater than the length of trip.

In some cases the operating conditions are such that loads are handled down the grade, while the cars are always empty when hauled up the grade. This often means that safe braking conditions require a heavier weight of locomotive than is necessary to ascend the grade with the empty cars. If the grades are short and without sharp curves at the base it is not so important to figure closely. However, when the grades are severe and long or have sharp curves at their base, the weight of locomotive should be figured in a manner to that in the above formula, except that the formula will be modified to subtract the frictional resistance of the load, since the frictional resistance assists the braking. The formula will then be:—

For cast iron wheels, $20 \times G \times A + 20 \times G \times W - FA = 400W$,
and, for steel wheels, $20 \times G \times A + 20 \times G \times W - FA = 500W$.

In case the grade, curve and track conditions are very bad and the question of safe handling down the grade is paramount then the adhesion factors of 20 percent for cast iron wheels and 25 percent for steel wheels should be decreased to suit the particular case.

Occasionally a locomotive is required for service which consists of very short runs with quick starts and stops as in coke oven service. A free running speed is never reached in this kind of service, and where high rates of acceleration and retardation are

used the weight of the locomotive will have to be increased accordingly. The unit of acceleration is generally taken as an increase in speed of one mile per hour for each second of time; i.e., if the rate of acceleration is 0.5 miles per hour per second, the increase in speed at the end of ten seconds will be five miles per hour. To accelerate a ton of dead weight at the rate of one mile per hour per second, a force of 91.3 lbs. above the frictional resistance must be applied.*

Since a locomotive has rotative as well as translative inertia the value 91.3 will be increased by an amount depending upon the speed and radius of gyration of the rotating parts. A safe figure to use for a mine locomotive and trip of cars would be about 95 lbs. per ton. In mine and industrial work where the speeds are from six to eight miles per hour, the rate of acceleration is, as a rule, taken at from 0.1 to 0.2 miles per hour per second.

If high rates of acceleration and retardation are to be used the weight formula will be as follows:—

For cast iron wheels, on level track, $FA + 95B(A + W) = 600W$.

Accelerating up a grade, $FA + 20G(A + W) + 95B(A + W) = 600W$.

Bringing trip to a stop on a down grade, $-FA + 20G(A + W) + 95B(A + W) = 400W$, where B is the rate of retardation in miles per hour per second.

For steel tired wheels, 666W can be used on level and up grades, while 500W should be used on down grades. The values 400W, 500W, etc., should be selected according to the service conditions.

The resistance of curves can be neglected, as a rule, unless they are long or have a short radius. Ordinarily only a small portion of the train will be on the curve at one time so that the draw-bar pull to be added should be calculated on the basis of the number of cars that can be placed on the curve at one time. The number of pounds per ton to be added for curves is rather high; the value will average 0.5 lbs. per ton per degree (about 0.3, however, for short curves with the gauge spread). The value

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*This figure is obtained as follows:—The force of gravity accelerates a given weight at the rate of 32.2 feet per second per second. A rate of one mile per hour per second, is equivalent to 1.46 feet per second per second. It will therefore require a force of $1.46 \div 32.2$ of the weight of a body to produce an acceleration of one mile per hour per second. $1.46 \div 32.2 \times 2\,000 = 91.3$ lbs per ton.

of a curve in degrees can be obtained by dividing 5 730 by the radius of the curve in feet.

Sometimes the weight of the locomotive figures out much too heavy for the weight of rails used in the proposition under consideration. If it is impractical to change the rails, the alternative is to reduce the number of cars per trip, so that the weight of locomotive can be reduced. A larger number of locomotives of the smaller type will then be required, but the cost of operation may be reduced by coupling them in tandem so that only one operator is required for two locomotives. In this way full trips can be obtained.*

EQUIPMENT

To determine the proper equipment for a locomotive it is necessary to know the general plan and profile of the road, the number of cars to be handled per trip and per hour, the weight of empty and loaded cars, frictional resistance of cars, the time of layover including switching and making up trip, voltage of circuit, gauge of track, weight of rail, radius and length of minimum curve, spread of track on this curve, limiting dimensions which the locomotive can have, and position and range of trolley wire.

The importance of obtaining the above information is not always fully realized; in fact, too often the imagination of the engineer, to whom mine projects are referred for recommendation, is depended upon to supply certain necessary data not specifically given.

The capacity of a motor for all-day service depends upon the temperature which the windings will attain. This temperature depends upon the average heating value of the current. Since the heating value of an electric current is proportional to the square of the current value, the average heating for all day service must depend upon the square root of the mean square of the current.

*Special Publication No. 7061 on Baldwin-Westinghouse Locomotives gives the following data in regard to safe weight of mine and industrial locomotives for various weights of rails:—

Locomotive Weight On Two Pairs of Wheels	Weight of Rail
Tons	Lbs. per yard
4 to 6	16
6 to 8	20
8 to 10	25
10 to 13	30
13 to 15	40
15 to 20	50

Two motors may have the same one-hour rating, but one may have a very much larger continuous rating than the other, due to better design and the proper distribution of the losses. A poorly ventilated motor will in some cases have "hot spots," and since "a chain is no stronger than its weakest link," these hot spots will lower the capacity of the motor. This is due to the fact that, in order to keep these spots within a safe temperature rise, the average temperature of the windings must be kept much lower than would be necessary if these spots were eliminated by proper design. That the real capacity of a motor is its continuous capacity for all-day service and not the rating for one hour is apparently not generally appreciated. The one-hour rating depends largely upon the thermal capacity of the motor, while the continuous rating depends on the ventilation, distribution of the losses and the capacity of the motor to radiate heat. The one-hour capacity is not a fair rating of a motor for the above reason and also for the reason that the speed of the motor is not taken into account. A fairer way would be to rate the motor on the pounds tractive effort at the wheels, irrespective of the speed, provided it is not considered essential for commercial reasons to capitalize the increased horse-power ratings due to increase in speed.

If the length of haul, the grade, curve, running time, and time of layover are known, the current for each part of the run can be computed. In most main haulage cases the locomotive will have a definite cycle to go through, this cycle being repeated throughout the working day. If the square root of the mean square current for one cycle can be found, this will of course determine the suitability of the motor selected for the all-day service as regards heating capacity.

After the weight has been determined, the motor equipment is selected from one of the motors designed for that particular weight of locomotive. By means of the motor curve the current and speed can be obtained for each part of the cycle. Each current value is then squared and multiplied by the time that it lasts. By adding all of these time-current-squared values and dividing by the total time including layover, the average squared value of the current is obtained. The square root of this value will give the root mean squared value of the current for a complete cycle. If the continuous capacity of the motor is above the root mean squared value the motor is of sufficient capacity, if

below it is not large enough and a larger motor should be selected. The continuous current capacity of mine motors is generally given at two voltages. If the service is main haulage and the hauls are fairly long with good line voltage, the value at the higher voltage should be used. If the service is gathering and switching or if the line voltage is very poor the value at the lower voltage should be used. The increased iron loss of the motor at the higher voltage is responsible for the lower current capacity.

When the locomotive is accelerating, the current is considerably greater than when running at constant speed. This together with the switching and making up of trips at the ends of the run produces extra heating and actual calculations show that this can be allowed for by adding ten percent to the sum of the time-current-squared values for fairly long runs, and 15 percent for short runs. The exact heating value of the accelerating currents can be calculated very closely but as a rule this is not necessary and can be taken care of by the above rule of adding 10 to 15 percent to the time-current-squared values.

To illustrate the working out of the above principles assume the following specifications for a drift mine:—

Locomotives required, 1; Gauge of track, 36 inches; Weight of rail, 30 lbs. per yard; Voltage, 250.

Minimum radius of curve, 30 feet, located near the foot of the two percent grade; length of minimum curve, 20 feet.

Maximum grade, two percent for 1 100 feet against load; no curve on this grade; also one percent grade for 1 000 feet against load; remaining part of run, level.

Total length of run, one way, 4 500 feet.

Weight of empty car, 2 000 lbs.; weight of load in car, 5 000 lbs.

Time for switching and making up trip, ten minutes for round trip.

Number of cars per trip, 20; number of cars to be handled in eight hours, 400.

Cars have self-oiling bearings.

Resistance of cars, 30 lbs, per ton.

Locomotives can be five feet wide, three feet high.

Trolley wire 2 feet 4 inches to right of center of track, and ranges from 4 feet 6 inches to 7 feet 6 inches in height.

From the weight formula it will be seen that the locomotive should weigh 13.6 tons with cast iron wheels and 10.6 tons with steel tired wheels, the limiting conditions being when the loaded trip is to be hauled up the two percent grade.

Steel tired wheels should be used unless there is some particular reason for using cast iron wheels. A standard ten ton locomotive should be selected, which means that the adhesion factor on the two percent grade will be 26.5 percent. This may mean an occa-

sional use of sand, and allows a margin for the increased draw-bar pull required in case it becomes necessary to start the trip on the grade. A locomotive with 30-inch wheels, a wheel base of 6.4 feet, and a total clearance between wheel flange and rail of 5/8 inch, will negotiate a 30 foot curve, so that the ten ton locomotive will have no trouble on the minimum curve since it is possible to build a ten ton locomotive with a wheel base of considerably less than 6 feet.

The number of cars handled per hour will be 50. Since each trip will consist of 20 cars, the time for each trip will be $20 \div 50 \times 60$ minutes $= 24$ minutes total time.

For a locomotive of a given weight there are, as a rule, several motors to choose from. For a ten ton locomotive these motors range from 40 to 50 horse-power in capacity, although larger motors are sometimes required for special cases. A 40 hp motor is selected for the first trial. The locomotive will have 30-inch wheels with a gear ratio of 5.83 to 1. The highest gear reduction is always selected unless a higher speed is required and can be obtained without overloading the motors. The characteristics of this motor are shown by the curves of Fig. 1. A table of data covering the case, such as shown in Table I or II, should be prepared, the values inserted being calculated from the motor curves and weights to be handled. Since the motor curves give values for one motor, the locomotive and trailing weight should be divided by two to give the weight each motor will be required to handle.

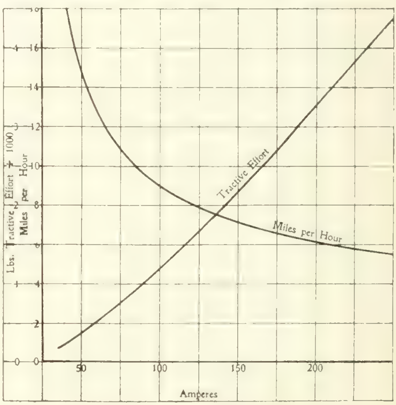

FIG. 1

For the above project the weight of locomotive is five tons per motor; the loaded trailing weight, 35 tons per motor, and the light trailing weight ten tons per motor. Assume that the locomotive starts with a load on a level track and runs 2 400 feet, when

it encounters a two percent grade. After ascending this grade for 1 100 feet the grade changes to one percent for 1 000 feet. The return haul will be with empty cars. Starting with the loaded trip on the level, the locomotive resistance per motor will be $5 \times 15 = 75$ lbs. This value is placed under "Locomotive Resistance" in the table. The train resistance will be $35 \times 30 = 1\,050$ lbs. The grade resistance will be zero. The total tractive effort will be 1 125 lbs. Consulting the motor curves of Fig. 1 the current for a tractive effort of 1 125 lbs. is 97 amperes and the speed 9.2 miles per hour. The time to cover 2 400 feet at 9.2 miles per hour will be 178 seconds.

TABLE I

Speed	Amp.	Total Tr. Ef.	Loco. Res.	Train Res.	Grade Res.	Time Sec.	Distance Ft.	Amp².	Amp². × Time
9.2	97	1 125	75	1 050	0	178	2 400	9 400	1 675 000
6.5	177	2 723	75	1 050	1 600	116	1 100	31 330	3 635 000
7.4	137	1 925	75	1 050	800	93	1 000	18 770	1 745 000
				RETURNING (Descending Grades).					
10	25	75	75	300	−300	60	1 000	625	43 100
10	0	−225	75	300	−600	75	1 100	0	
10	50	375	75	300	0	104	2 400	2 500	410 000

Total running time, 695 seconds.

Amp.² × time (running) in seconds	7 508 100
Plus 10% for accelerating, switching	750 810
Total amp.² time in seconds	8 258 910

Total time, including layover = 1 440 seconds.
$8\,258\,910 \div 1\,440 = 5\,740$ = mean squared current.
The square root of $5\,740 = 75.8$ = square root of mean square current.

The amperes squared will be 9 400 and the amperes squared multiplied by time will be 1 675 000. These values should be recorded in their proper place in the table. When the train reaches the two percent grade, the train and locomotive resistance remain the same while the grade resistance will be $40 \times (35 + 5) = 1\,600$ lbs. The total tractive effort will be 2 725 lbs. which corresponds to a motor current of 177 amperes and a speed of 6.2 miles per hour. At this speed it will require 116 seconds to travel 1 500 feet. By the same process the values for the one percent grade are calculated and filled in the table. On the return trip with the empty cars the locomotive resistance will be the same, the train resistance

300 lbs. for ten tons, and the down grade resistance — 300 lbs. for the one percent, and — 600 lbs. for the two percent grade. It will be noted that, running down the two percent grade, the net tractive effort is — 225 lbs., which means that the brakes must be applied in descending this grade.

On the one percent grade and on the level the speeds shown on the curve of Fig. 1 are too high for most mines unless the track is in good shape. It is likely that the operator will not care to run faster than ten miles per hour, which he can do by operating the motors in series on low notches, or by cutting off the power

TABLE II

Speed	Amp.	Total Tr. Ef.	Loco. Res.	Train Res.	Grade Res.	Time Sec.	Distance Ft.	Amp².	Amp². × Time
9	95	1 125	75	1 050	0	182	2 400	9 025	1 642 000
6.7	172	2 725	75	1 050	1 600	112	1 100	29 600	3 315 000
7.6	130	1 925	75	1 050	800	90	1 000	16 900	1 520 000
RETURNING (Descending Grades).									
10	35	75	75	300	−300	69	1 000	1 225	84 500
10	0	−225	75	300	−600	75	1 100	0	
10	50	375	75	300	0	164	2 400	2 500	410 000

Total running time = 692 seconds.
Amp.² time (running) in seconds.............................. 6 971 500
Plus 10% for acceleration, switching, etc...................... 697 150

Total amp.² × time in seconds............................ 7 668 650

Total time, including layover = 1 440 seconds.
7 668 650 ÷ 1 440 = 5 325 = mean squared current.
The square root of 5325 = 73 amp. = square root of mean square current.

and coasting before the speed becomes too high. The total running time is 695 seconds or 11 minutes 35 seconds. The actual running time will be from 12 to 14 minutes, due to time taken to start and stop the trip and for slowing down at cross-overs. As the total time for a round trip is 24 minutes, a layover of five or six minutes is obtained at each end. The product of the total current squared by time is 7 508 100. To this, ten percent should be added to allow for acceleration and switching when making up trips, making a total of 8 258 910. The total time for making a round trip including layover is 1 440 seconds. Dividing 8 258 910 by 1 440 = 5 740 as the mean square of the current. The square root of 5 740 is 75.8 amp. which is the square root of the mean

square current for one trip or cycle. The continuous capacity of the motor is 68 amp. at 150 volts and 64 amp. at 200 volts. The class of service is such that the average voltage applied to the motor will be near 200, so that the rating of the motor is about 65 amp., which shows that it is not of sufficient capacity for the service. Care should be taken that a motor is not selected in which the commutating limit is exceeded when the wheels are slipped while using sand. The motor curves are generally stopped at the commutating limit.

A larger motor should be selected and Table II shows the results of the calculation using two 50 horse-power motors. The curves of Fig. 2 show the characteristics of this motor. The total running time is 692 seconds or 11 minutes 32 seconds. The square root of mean square current is found to be 73 amperes. The capacity of the motor at 200 volts is about 72 amperes so that this motor will be of just about the proper capacity to meet the conditions. The actual running time will be about 12 to 14 minutes, allowing five to six minutes to start and stop the trips and for slowing down at curves and cross-overs.

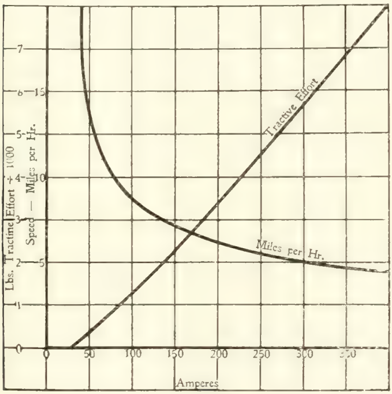

FIG. 2

It is not safe to figure on a very short layover as in many cases the average line voltage is much less than 500 or 250 volts, which means that the speed will be less than is figured on. A low line voltage means that a given current will be required for a much longer time than with normal voltage, which in turn means additional heating. Where the voltage is likely to be poor, a margin should be allowed in the motor capacity, since the value of the square root of mean square current will be greater than that calculated upon.

When a locomotive is to be used for gathering service, it is

when the service is for main haulage. The operation consists almost entirely of acceleration and braking, and with varying weights, grades and curves. From experience it has been found that, if the horse-power per ton weight of locomotive is from six to ten, the motor will be of ample capacity for gathering service.

There seems to be a prevailing idea among mine operators in regard to placing larger motors on their mine locomotives than are indicated by actual calculation. This is an erroneous attitude unless justified by contemplated future extensions. It is true that, in the past, the motor equipment of many locomotives has been made too small; the present tendency, however, seems to be just as strongly in the other direction. The placing of too large motor equipment on a locomotive is practically analogous to hitching a heavy dray horse to a small express wagon; the horse cannot be worked at his capacity, and in fact is likely to injure the wagon in attempting to perform his normal work. When the motor capacity is too large for the locomotive, the extra power that is available cannot be utilized, and in also the mechanical wear is so great that the greater cost for upkeep outweighs the saving in motor repairs.

Control Details—The resistance type of controller with a combination series-parallel and reversing switch, is generally used for mine locomotives. As each controller has a definite capacity of 250 and 500 volts, care should be exercised in selecting the proper controller for a given motor equipment. In selecting the control resistance it is very important to provide ample current carrying capacity as well as correct ohmic resistance. Control taps on the resistance should be so selected as to give a smooth start and uniform increase in tractive effort for each controller notch.

A circuit breaker should be used only on locomotives of eight tons and over. On the smaller locomotives a fuse is more satisfactory. In selecting a circuit breaker, its continuous carrying capacity should be somewhat greater than the capacity of the two motors combined, since the thermal capacity of the circuit breaker is much less than that of the motors. The circuit breaker should be set at the current value corresponding to the current which both motors will take when the locomotive is exerting a tractive effort of forty percent of the weight on the drivers. This will insure against opening of the circuit breaker under ordinary operating conditions, but will allow for its opening in case of trouble.

COMPARISONS OF GROUP AND INDIVIDUAL DRIVE IN MACHINE SHOPS

A. G. POPCKE

THE fundamental question for an engineer or shop manager to determine in deciding what method of drive to employ in a shop is:—What apparatus shall be installed in order that the greatest returns may be received from the investment? A satisfactory answer requires a thorough analysis of first cost and operating expenses. The first cost of individual drive is commonly assumed to be in excess of the first cost for group drive. It will be shown by the following analysis that this is not always the important consideration. In explanation, the results of a test made in a large machine shop will be used; the method of procedure in making a test of this kind will be explained and figures based on actual practice will be given. In making these tests a graphic recording meter was used. This type of meter is most accurate and useful for investigations of this kind, since a complete record of power consumed at every instant of time is recorded over any period and average conditions of operation are obtained by this method.

The machine shop here used as an example was steam engine driven. A 300 horse-power, 85 r.p.m. steam engine was belted to jack-shafts on each of six stories, as shown in Fig. 1. The line shafting of each floor was connected to this jack-shaft drive through clutches, by means of which the machinery on any floor could be disconnected at any time. This method of drive made it possible to obtain a value for the relation between no-load friction and full-load friction of the jack shafting. Table I shows the results obtained by taking indicator cards on the steam engine. With the line shafts on all floors disconnected 32 horse-power was required to drive the jack shafting. The average load on any floor was obtained by subtracting from the total load, the load remaining after the floor under consideration was disconnected by means of the clutches. The sum of the loads for each floor obtained in this way was 196.7 horse-power. The total load averaged 272.2. The remainder, therefore, 75.5 horse-power, was the full-load friction of the jack shafting. This is 2.35 times the no-load friction. The cost of power for the jack-shaft friction per year of 2 808 hours was figured at two cents per kilowatt-hour or 1.5 cents per horse-power-hour. This

amounted at no load to $0.015 \times 32 \times 2\,808 = \$1\,340$ per year; and at full load to $0.015 \times 75.5 \times 2\,808 = \$3\,160$ per year.

Due to the large number of idler pulleys and heavy belts, the latter varying from 10 to 21 inches in width, the increase from light-load friction to full-load friction is probably higher than it is for ordinary line shaft drive. For the latter the increase can safely be estimated at approximately one-half the above or 70 percent increase. This value will be used in the subsequent discussion.

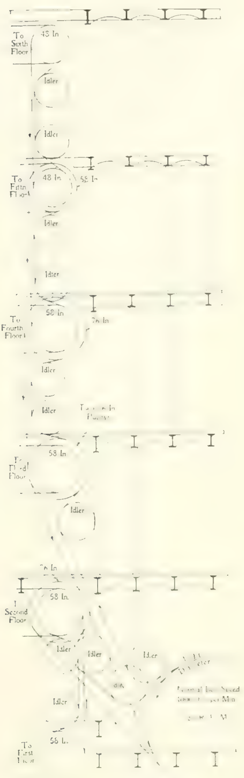

FIG. 1 — ELEVATION OF JACK SHAFT AND BELT DRIVE— TYPICAL SIX-STORY BUILDING

The owners of this plant were quite conservative in their methods and were not familiar with the economies of electric drive, but were willing to allow a series of tests to be made. Their intention was to replace the steam engine driving the heavy jack-shaft with a large electric motor. A 300 horse-power motor driving the jack-shaft would be required to take care of the total load of the building, which, at 500 r.p.m. would cost about $2 800. The friction load of the jack-shaft drive, based on full-load per year, would be more than the first cost of the motor itself. This fact alone proved conclusively the poor economy of the use of a jack-shaft drive which is a necessity with a single steam engine or motor as a source of power.

The next step was to divide the load on the various floors into groups, arranged most advantageously for motor drive, considering the shop conditions, such as arrangement of shafting, necessity for overtime work, type of machine, etc. A 30 horse-power, 850 r.p.m. induction motor was used to make these tests, and the test groups were so selected that this motor would carry the load successfully. Figs. 2 and 3 show characteristic records. Fig. 2 is an example of a moderately loaded shop, and Fig. 3

shows plainly the excessive waste of power due to line shafting where the work on the machines is light and the machines connected to the shafting are scattered.

Table II contains a summary of the power consumed on the various floors. In this installation the speed of main shafting

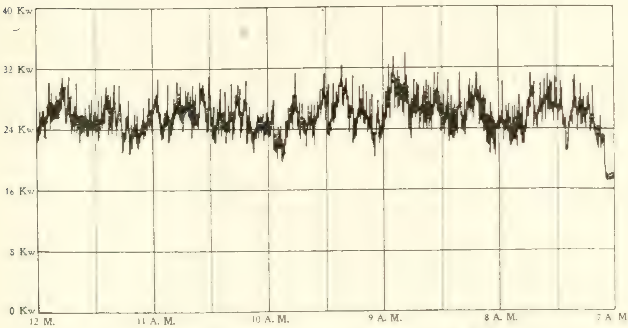

FIG. 2—GRAPHIC METER RECORD—FLOOR 2

Characteristic record of shop where the machine tools are working at a moderate rate

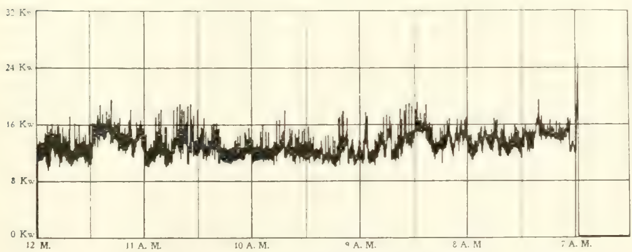

FIG. 3—GRAPHIC METER RECORD—FLOOR 3

Characteristic record of a shop where the work is light and machines are scattered. The friction load, just after the motor was started and before the load was thrown on, is about 13 kw.

is from 180 to 200 r.p.m.; there is a self-oiling bearing every eight feet, a coupling every 16 feet. The hangers are mounted upon I-beams. The overhead work is kept in good condition, being thoroughly lined up once a year. The countershafts are examined and oiled once a month. Beside the figures obtained by observation and test as to number of machines, feet of main shafting, friction

load, average load and maximum load, the table contains the following calculated analytical values:—

1—Percent of friction load to average load. This is an indication of the amount of power wasted by the overhead shafting.

2—Percent of maximum load to average load. This shows the overload capacity with which a driving motor must be provided.

3—The feet of main shafting per kw loss, an indication of the condition of the shafting, provided the number of machines connected thereto is also considered.

4—The feet of main shafting per machine tool, an indication of the number of machines. The smaller this value the more crowded the shop.

5—The friction loss per machine is the amount of power which must be charged to each machine tool for overhead friction loss.

6—The average load per machine indicates the average power consumed by each machine and is a criterion of the size of motor that would be required for individual drive, provided the proper time load-factor and relation of average to maximum load is considered.

It is interesting to note that the friction loss of line shafting per machine (average 200 watts) is equivalent to the power consumed by four 16 cp carbon incandescent lamps, or, on a more modern basis, the equivalent of five 40 watt, 32 cp tungsten lamps. A shop superintendent will reprimand a man if he allows a 16 cp lamp to burn in broad daylight, but he does not realize that the overhead line shafting per machine tool is consuming as much power as three or four of these lamps.

In comparing the average load per floor, given in Tables I and II, it is seen that on the upper floors the load is greater when measured electrically. Besides the fact that more machines were running during this test than when the engine was indicated, it was found that when connected to the jack shafting the speed of the line shafting was less than intended. This fact was discovered by an increase in production of five to seven percent on the automatic gear machines on the sixth floor when the electric motor was connected to the shafting. The shafting ran at the standard speed (150 r.p.m.) when motor driven. The difference in output results in a proportionate difference in the amount of power consumed. This case emphasizes the fact

that there are excessive losses of production in shops due to the slippage of belts, the loss increasing with the distance from the source of power.

The relation of these losses to the comparative first costs of individual and group drive can be best shown in tabular form. The following analysis is given as an example, using the fourth floor for this purpose.

GROUP DRIVE—COST OF INSTALLATION

MAIN SHAFTING:		
796 ft. 2 15/16″ Shafting at $0.523		$ 418.00
100 Keyways for couplings 0.374		37.00
100 Hangers (25″ drop)		1 055.00
50 Couplings at $7.44		372.00
3 Clutches		345.00
Labor to install ($0.14 per ft.)		112.00
		$2 339.00
Cost per foot of main shaft	$ 2.90	
Number of machines, 136		
Cost per machine	17.20	
Feet per machine 5.9		
COUNTER SHAFTING (136 Machine tools):		
Machine tools—136 × $30		$4 080.00
Labor $2.50 × 136		340.00
Belts (55 ft. per machine, average width 3″ single, 136 × 55 × 0.13		970.00
Pulleys on main shaft (10″ average) 2 × 136 × $2.00		544.00
		$5 934.00
MOTORS:		
50 hp at 850 r.p.m.		$ 450.00

SUMMARY OF COSTS:		Per cent of total
Main shaft	$2 339.00	27
Counter shaft and pulleys	4 964.00	57
Belts	970.00	11
Motor	450.00	5
Total	$8 723.00	100

GROUP DRIVE—COST OF POWER FOR FRICTION LOSS

The total no-load friction loss in line shafting and belts (Table II) is 26 kw. At two cents per kw-hour and 2 808 hours per year, it would cost $1 460 per year. The loss increases approximately 70 percent with load, so the cost of full-load friction would be $2 480 per year.

INDIVIDUAL DRIVE—COST OF INSTALLATION

On the average a two hp, 1 120 r.p.m. motor will be required to operate each of the machine tools in the above group. Motors of constant speed type can be used in the majority of cases.

Cost per motor if alternating current is used	$ 64.00 net
Total cost for 136 machines—136 × 64 =	8 700.00
Add 20 percent for wiring, extra attachments, etc.	10 500.00

INDIVIDUAL DRIVE—COST OF POWER FOR FRICTION LOSS

The average no-load loss per motor equals 200 watts. This is, of course, a condition not met with in practice, but may be used for comparisons, and for extremely light cuts. The no-load loss of all machines running light $= 136 \times 0.2 = 27.2$ kw, But the time load-factor based on working hours for machines of this type is 25 percent.

Average friction load $0.25 \times 27.8 = 6.8$ kw.
Cost per year $= 2\,808 \times 0.02 \times 6.8 = \$382$ per year.

TABLE I—COMPARATIVE FRICTION AT NO-LOAD AND FULL-LOAD—JACK-SHAFT DRIVE.

Total Load.	Total horse-power with one floor disconnected.		
	Floor Removed.	Horse-power.	Horse-power per floor.
270.3	6	195.5	74.8
271.0	5	241.0	30.
273.6	4	235.8	37.8
272.	3	257.1	14.9
272.2	2	245.3	26.9
272.2	1	259.9	12.3

Full load ....272.2 hp.
Sum of floor loads....................................196.7 hp.

Difference—full-load friction of jack-shafts.......................... 75.5 hp.
No-load friction of jack-shafts, by test.............................. 32.2 hp.

The full-load losses of the motor and transmission losses in the wiring can be estimated at 80 percent increase over no-load losses. These are, therefore, $1.80 \times 382 = \$690$ per year.

DIFFERENCE IN FIRST COSTS

Individual drive $10 500
Group drive 8 723

Difference .... $ 1 777

DIFFERENCE IN FRICTION LOSSES

Based on no-load friction—
Group drive .... $2 480 per year
Individual drive .... 690 " "

Difference $1 790

TABLE II—ANALYSIS OF POWER CONSUMPTION

	Building-A						Building-B	
Floor No. (See note for type of machines)	1	2	3	4	5	6	1	2
No. of machine tools	24	85	40	136	71	183	52	97
Feet of main shafting	260	417	330	796	617	760	233	528
No-load friction loss	11.4	16.5	11	26	20	31	9	19
Average load—kw	16	27	13	48	52	93.5	24	41
Percent $\left\{\frac{\text{frict'n loss}}{\text{aver. load}}\right\}$	71	61	85	54	38.4	33	37.5	46.4
Max. load—kw.	20	32	19	54	65	118	36	60
Percent $\left\{\frac{\text{Max. load}}{\text{aver. load}}\right\}$	125	118	146	113	125	126	150	146
Feet of main shafting per kw friction loss	23	25	30	31	31	25	26	28
Feet of main shafting per machine	10.8	4.9	8.25	5.85	8.7	4.15	4.5	5.45
Friction loss per machine tool—kw	0.475	0.194	0.275	0.191	0.282	0.17	0.173	0.196
Average load per machine	0.067	0.318	0.325	0.35	0.73	0.51	0.46	0.42

The following is a list of machines connected to the shafting on the various floors.

BUILDING A

Floor 1—Eight horizontal boring mills; four small lathes; one drill; two centrifugal separators; carpenter shop consisting of two 36-inch band saws; three 14-inch buzz saws; two 12-inch planers; one speed lathe and one grindstone.

Floor 2—Thirty-seven 10 to 20-inch lathes; twenty-one milling machines; nineteen 12 to 24 inch drills; seven 4 to 5-ft. radial drills; one grinder.

Floor 3—Twelve 12 to 24-inch drills; eleven 10 to 24-inch lathes; eleven milling machines; four 5-ft. radial drills; two tool grinders.

Floor 4—Eighty-one 12 to 36-inch lathes; thirty-two milling machines; five small planers; thirteen 10 to 24-inch drills; three 4 to 6-foot radial drills; two horizontal boring mills.

Floor 5—Forty-six grinders, buffers and polishers; fifteen automatic turret lathes; ten miscellaneous machines, as small lathes, drills, slotters and tool grinders.

Floor 6—110 automatic gear millers; thirty-two gear planers; forty-one 10 to 20-inch lathes.

BUILDING B

Floor 1—Twenty 12 to 20-inch lathes (moderate duty); thirteen 30 to 48-inch vertical boring mills; six 12 to 24-inch drills; four 60 to 90-inch heavy vertical boring mills; three small planers; three milling machines, two tool grinders; one 6-ft. radial drill.

Floor 2—Forty-two 12 to 24-inch lathes; thirty-three milling machines; ten 4 to 6-foot radial drills; five small drills; five horizontal boring mills; two tool grinders.

TIME TO PAY FOR DIFFERENCE IN FIRST COST BASED ON MONEY SAVED IN FRICTION LOSS

Based on no-load friction .... $\frac{1\,777}{1\,078} = 1.65$ years.

Based on full-load friction .... $\frac{1\,777}{1\,790} = 0.99$ year.

This shows that the difference in first cost will be paid for in two years, if the difference in friction loss alone is considered

TABLE III

ANALYSIS OF FIRST COST AND COST OF FRICTION LOSS.

In Group-Driven and Individual-Driven Machine Shops. Cost of power is based on 2 cents per kw-hr.

	Building A				Building B	
Floor number	2	4	5	6	1	2
No. of machines	85	136	71	183	52	97
Feet of main shafting	417	796	617	760	233	528
Group drive						
Cost of installation of main shafting	$1 495	$2 339	$1 674	$2 240	$ 692	$1 315
Counter shafting and pulleys...	3 102	4 964	2 592	6 680	2 030	2 541
Belts	607	970	510	1 310	745	694
Motors	317	450	1 323	1 222	386	416
Total	$5 521	$8 723	$6 099	$11 452	$3 853	$4 966
Cost of friction load per year						
Based on no-load............	$ 930	$1 460	$1 125	$1 740	$ 507	$1 070
Based on full-load	1 580	$2 480	$1 900	$2 960	$ 865	$1 820
Individual drive						
Average hp. of motor	2	2	3	3	3	2
Cost of motors plus 20%	$6 550	$10 500	$6 360	$16 800	$4 750	$7 500
Cost of friction load per year						
Based on no-load	240	$ 382	$ 220	$ 562	$ 161	$ 273
Based on full-load...........	430	690	396	1 010	290	490
Difference between costs of group and individual drives.						
First cost	$1 029	$1 777	$ 261	$5 348	$897	$2 534
Friction load						
Based on no-load friction ...	$ 690	$1 078	$ 905	$1 178	$346	797
Based on full-load friction ...	$1 150	1 790	1 504	1 950	575	1 330
Time to pay for difference—years						
Based on no-load friction	1.5	1.65	0.29	4.5	2.6	3.2
Based on full-load friction ..	0.9	0.99	0.17	2.7	1.6	1.9

Floors *1* and *3* building *A* have been omitted because the main shafting per machine tool is high, putting group drive naturally at a disadvantage. The excess space on these floors is used for testing purposes.

at two cents per kw-hr. The friction loss in large shops is one of the least important items of the operating expenses, since the total power consumed is usually only one or two percent of the total operating expenses. If the cost of installing individual motors was 50 percent of their cost, instead of 20 as above assumed, the difference in first cost would be $4 277, and the difference in cost of friction (average between full and no-load) $1 439—the difference would be paid for in three years.

Table III gives the results of a similar analysis of costs for the remaining floors referred to Table I.

These figures show that if the proper motor is used for individual drive, the difference between the cost of individual and group drive is not large, if a new shop installation is considered, and will be paid for in two years' average. Instead of investing money in shafting and belting, it can be more economically invested in the purchase of electric motors for individual drive. It must be remembered that the condition of the overhead work upon which these results have been based is ideal compared with that of the average machine shop where line shafting is more or less out of alignment, bearings and counter-shafts are loose and belting covered with oil. In these cases the friction losses are greater and the individual motors would show still greater advantage. With higher cost of power the advantage is also greater.

In cases where an old shop is completely equipped with line shaft drive it might not pay to scrap all the overhead work already installed at once, the loss in production being too great, but whenever new machine tools are purchased, or whenever changes are made in a shop layout, the problem should be investigated in a manner similar to that above outlined to determine the advantages of each type of drive from an economic point of view. In the majority of cases individual drive will show the greatest number of advantages.

POLYPHASE INDUCTION REGULATOR WINDINGS.

E. E. LEHR.

POLYPHASE induction regulators are wound with a distributed type of winding such as used on practically all alternating-current motors and generators. In checking regulator windings difficulties are met which are not involved when motor or generator windings are considered. Not only must each winding of the rotor and stator be correct when considered by itself, but the rotor must have a definite angular position relative to the stator in order that the mechanical maximum and minimum positions will coincide with the electrical maximum and minimum positions. A brief description of the operation of a regulator will serve to illustrate this point. A three-phase regulator has three primary (shunt) circuits or windings, which are usually placed on the rotor. These may be connected either in star or delta to the circuit the voltage of which it is desired to regulate. There are three separate series (secondary or regulating) windings, usually placed on the stator. Each of these windings has two leads brought out through the case so that it can be connected in series with one lead of the three-phase circuit. Since the voltage impressed upon the shunt windings produces a rotating magnetic field, and since this magnetic field also cuts the conductors composing the series windings, there will be generated in each of the three series windings a voltage of practically constant value regardless of the angular position of the series coils. The phase direction of the voltage in each of these series coils will vary however, depending upon the relative angular position of the rotor and stator. Since the series coils are in series with the line, whatever voltage is induced in these coils will be added vectorially to the line voltage. If the respective primary and secondary voltages are in phase and in the same direction a maximum voltage will be obtained on the feeder side of the regulator. If the respective voltages are in phase but in opposite directions a minimum voltage will be secured. In any other position the voltage will be intermediate between the extreme values. The usual connections for a three-phase regulator with primary windings connected in star are indicated in Fig. 1, while Fig. 2 shows a vector diagram of the same regulator, in which ABC represents the line voltage; AA_1, BB_1 and CC_1 represent the voltages of the three series coils. These assume various positions, three of which are shown in the diagram. The resulting feeder voltages

for these three positions are indicated as $A_1 B_1 C_1$; $A_2 B_2 C_2$ and $A_3 B_3 C_3$. It should be noted that the phase of the resultant feeder voltage is also slightly changed with the regulator in its various positions. For example, the voltage $A_1 B_1 C_1$ is not in phase with $A_2 B_2 C_2$. For this reason polyphase regulators should never be operated in parallel unless provision is made for properly connecting the rotors together mechanically so that they will both be operated together; a considerable idle current may circulate through the regulators, even when the respective voltages across the terminals of each are practically the same.

The use of vectors in checking windings insures the most satisfactory and reliable results. A detailed description of the method

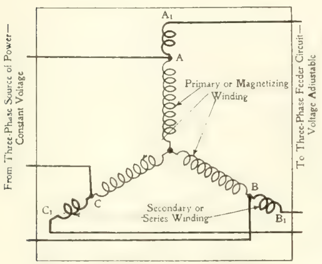

FIG. 1—DIAGRAM OF CONNECTIONS OF THREE-PHASE FEEDER REGULATOR

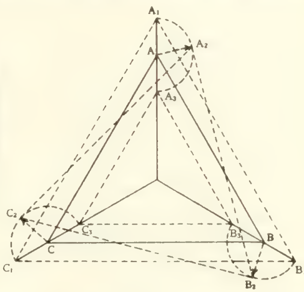

FIG. 2—VECTOR DIAGRAM OF THREE-PHASE REGULATOR

Incoming line voltages: ABC. Regulator secondary voltages: AA_1, BB_1, CC_1, giving resulting outgoing line voltages varying between the limits $A_1B_1C_1$ and $A_3B_3C_3$, according to the relative position of rotor primary to stator secondary of regulator.

as applied to a particular case will give a general idea as to the method of procedure, and its general application to other cases will be apparent.

Consider a two-pole, three-phase regulator, with a stator or secondary having 24 slots and windings of the concentric type with one coil per slot, as shown in Fig. 3*a*. The rotor or primary has 18 slots and the windings are of the diamond type with two coils per slot and a throw of 1 and 8, as shown in Fig. 4*a*. When a regulator is in operation a revolving magnetic field is produced. Any conductor in a slot of either the rotor or stator will have induced in it an alternating voltage of definite phase relation, which can be represented by a vector as shown within the connection diagrams of Figs 3*a* and 4*a*. By combining the individual vectors of all the

conductors of each phase by the usual method of vector addition as indicated in Figs. *3b* and *4b,* three vectors for the rotor and three vectors for the stator will be obtained which represent the resultant voltages of the windings in their true phase relations. Fig. 5 shows the conductors only of the stator and rotor as given in Figs. *3a* and *4a,* and indicates the position which they assume when the regulator is in the position of maximum "boost." The vector diagram on the inside shows the resultant vectors representing the combined voltages of all the conductors of the respective three phases. The same arrangement with the rotor or primary rotated through 90 electrical degrees is shown in Fig. 6. This is the position which the windings assume when the regulator is in the neutral or mid-position.

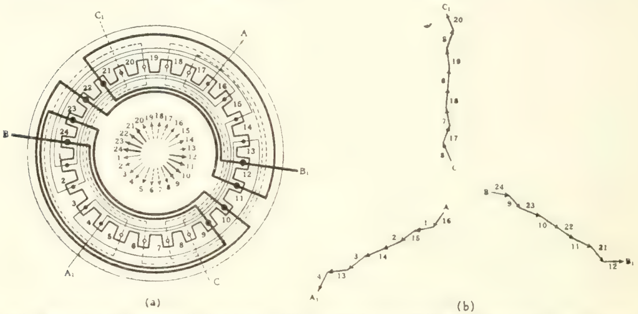

FIG. 3—STATOR WINDING DIAGRAM AND VECTOR DIAGRAM OF VOLTAGES OF THREE-PHASE, TWO-POLE INDUCTION REGULATOR

Showing method of adding vectors corresponding to the respective conductors of each phase to obtain total voltages and their phase relations.

Lower coil ends shown on inside in diagram (a); connections between coils shown on outside.

tral or mid-position. When the rotor is turned through 90 additional degrees it comes into the position of maximum "buck" as indicated in Fig. 7. In each of these three figures the vector diagram shows the voltages of the various phases of primary and secondary in their true phase relation. These diagrams show clearly the fact that the voltage variations obtained from a three-phase regulator are obtained by shifting the phase of the primary coils relative to the series or secondary coils. A, B, C represent the constant or busbar voltages and A_1, B_1, C_1 represent the feeder voltages. The voltages of the three series coils AA_1, BB_1, and CC_1 are practically constant regardless of the position of the rotor windings.

Some uncertainty may be caused by the apparent reversal of half the vectors of Figs. *3a* and *4a* in order to obtain the combined

vectors in Figs. 3*b*, 4*b*, 5, 6 and 7. It should be understood, however, that in Figs. 3*a* and 4*a* each vector represents the voltage of the conductor assumed as running through the slot from top to bottom of the core. In Figs. 3 and 4 by tracing out any phase it will be noted that half the conductors are traced in the opposite directions, that is, from the bottom through the slot to the top. Although only one conductor per coil is shown in the diagram, each coil is made up of a number of turns. All the conductors in one slot have generated in them voltages of practically the same phase direction and same value, so that a change in the number of turns affects only the length of the vector and does not affect its direction. In a three-phase star-connected regulator, giving ten percent

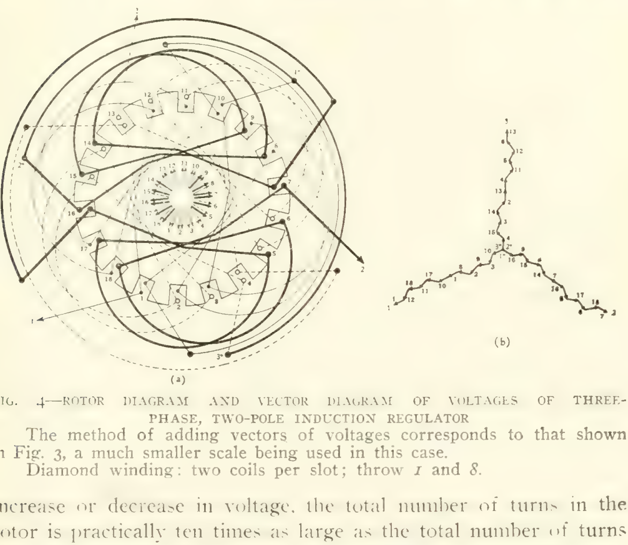

FIG. 4—ROTOR DIAGRAM AND VECTOR DIAGRAM OF VOLTAGES OF THREE-PHASE, TWO-POLE INDUCTION REGULATOR

The method of adding vectors of voltages corresponds to that shown in Fig. 3, a much smaller scale being used in this case.

Diamond winding: two coils per slot; throw *1* and *8*.

increase or decrease in voltage, the total number of turns in the rotor is practically ten times as large as the total number of turns in the stator so that the relative lengths of the vectors of rotor and stator should be approximately in the ratio of 10 to 1. This is only approximately true, for if the windings are chorded the ratio of secondary to primary voltage will vary considerably from the ratio between stator and rotor turns.

The same number of slots should never be used on the rotor and stator. If this is done there will be a tendency for the teeth to "lock magnetically" when they are in line, and considerable additional tor-

que will be required to operate the regulator. Under these conditions vibration and noise are also likely to result.

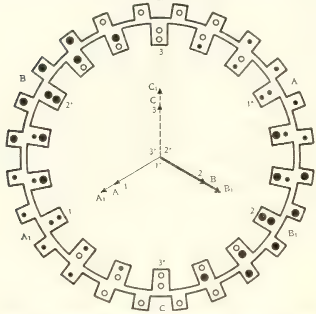

FIG. 5—PLAN VIEW OF REGULATOR SHOWING RELATIVE LOCATION OF PRIMARY AND SECONDARY CONDUCTORS WITH ROTOR IN POSITION OF MAXIMUM BOOST

RULES FOR CHECKING

A systematic method of determining whether the windings of a regulator which has been completed are correctly placed and connected is indicated by the following rules:—

Lay out a plan view of the rotor and stator slots in the position they assume when regulator is in mid-position, as shown in Fig. 6. By means of winding diagrams indicate the conductor in each slot, giving the conductor of each phase a characteristic symbol. Designate the various phases by letters, remembering that these markings should be placed symmetrically with respect to the conductors in any group; for example, although the lead A comes out of slot *16* of the stator and lead A_1 comes out of slot *4* (as indicated in Fig. 3*a*) the center line of this phase should be placed between slots *14* and *15*, and slots *2* and *3* of the stator. This center line then determines the direction of the series vector corresponding to this phase.

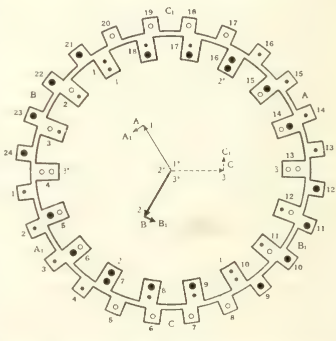

FIG. 6—PLAN VIEW OF REGULATOR SHOWING RELATIVE LOCATION OF PRIMARY AND SECONDARY CONDUCTORS WITH ROTOR IN NEUTRAL OR MID-POSITION

The voltage induced in any of the windings can now be shown by vectors parallel to the center line of the various windings. The vector of the voltage in the primary winding *1* and *1** of Fig. 6 is parallel to the center line of slots *1* and *10* of the rotor. The vector of the stator winding AA_1 is parallel to the center line of the tooth between slots *2* and *3* and

the tooth between slots *14* and *15*, as noted above.

Draw the vector diagram as shown in the inner portion of Fig. 6. This diagram should be symmetrical and the vectors of the secondary windings should be at right angles to the vectors from the neutral point to the points *A*, *B* and *C*. If the regulator has four or more poles the same procedure should be followed except that only the slots which make up two poles of the regulator should be used in the diagram. This is necessary in order that the mechanical angles of the windings may coincide with the electrical angles of the voltages considered. Although this method is somewhat cumbersome in description, its familiar application will show it to be a convenient and quick means of setting up and checking windings. When this method of checking is employed the only other check that need be made on the windings is to determine whether any group of coils is reversed. For instance, in a six-pole winding since only the slots composing two poles are indicated in the plan view made for checking purposes the winding diagram must also be checked to see that in any phase, when tracing the winding from one terminal to the other, all the conductors under one pole are traced in the same direction and conductors under adjacent poles are traced in the opposite direction.

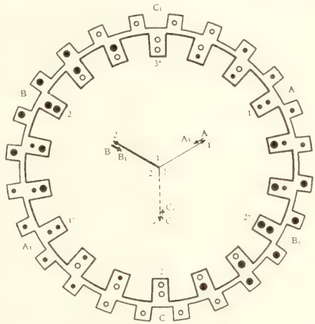

FIG. 7—PLAN VIEW OF REGULATOR SHOWING RELATIVE LOCATION OF PRIMARY AND SECONDARY CONDUCTORS WITH ROTOR IN POSITION OF MAXIMUM BUCK

MOTOR DRIVE FOR BISCUIT FACTORIES

V. L. BOARD

THE freedom with which the electric motor can be used as an independent drive for a single machine, or group of machines, as compared with other sources of power, and its ability to operate under unfavorable conditions is a great advantage in bakeries and biscuit factories. A superintendent of a large buscuit factory stated recently, that the advantage of having a separate drive for dough mixers alone justified the use of electric motors in his factory.

The product of a biscuit factory may be divided into two general classes, products made directly from sponge, such as soda crackers, forming one class and those made from especially prepared dough, such as any sweet biscuits, making up another. The general process of manufacture of these two classes of products is about the same, and consists in preparing the sponge or dough, in shaping or cutting the biscuits, and in baking. After baking, the sponge products are packed at once, while a portion of the "sweet" products (depending upon their nature) may be given some sort of special treatment, such as icing, before they are packed. In the process of manufacture use is made of power-driven dough mixers, cutting or forming machines, reel ovens, packing or special conveyors and icing machinery, and, incidentally, elevators, box-nailing machines, etc. Practically all these machines run at slow-speed, so slow, in fact, that any motors that might economically be used for driving them require considerable speed reduction. In arranging the drives for a factory, therefore, this feature should be borne in mind in order that the individual drive shall not be carried too far. It may be more economical, from the standpoint of gear losses alone, to use a single motor with a short line shaft to drive several adjacent machines which are commonly operated at the same time, than to give each machine a separate drive.

The polyphase induction motor seems to meet the demands of this class of service with the most satisfaction. Where the direct-current motor has been used, an unusual amount of commutator trouble has been experienced in most instances, as flying particles of flour collect on the commutator and form a sort of hard "cake" which causes considerable sparking and necessitates frequent cleaning. This difficulty has been overcome in some cases by using enclosed motors, but this, of couse, involves a considerable

reduction in motor capacity. The polyphase induction motor can be used without enclosing, and will operate satisfactorily even after the windings and all parts of the machine, both stator and rotor, have become completely covered with the caked flour.

The following description, while applying specifically to an electrically operated biscuit factory in one of the large western

TABLE I—MOTORS INSTALLED IN BISCUIT FACTORY

No.	Horse-power	R.P.M.	DRIVING
		SWEET DEPARTMENT	
1	20	1 200	1 6 bbl. dough mixer 2 1 bbl. soft dough mixers
1	10	1 200	1 Cutting machine 1 Press 1 Soft dough cutting machine 1 Dough roller
1	5	1 200	Reel oven
1	5	1 800	Packing conveyor
		SPONGE DEPARTMENT	
1	10	900	7 bbl. dough mixer
1	5	1 200	Dough roller
1	10	1 800	Cutting machine
1	5	1 200	Oyster cracker conveyor Reel oven
1	5	1 200	Pan tower
		ICING DEPARTMENT	
1	10	1 800	2 Marsh mallow beaters 1 Icing machine 1 Chocolate melangeur 1 Fruit grinder 1 75 gal. stirring kettle 1 chocolate grinder
1	5	1 200	Icing conveyor
		SPECIAL MOTORS	
1	5	1 200	Box machine
2	10	1 200	Elevators
1	5	1 200	Polishing brushes

cities, is intended to give a general idea of the conditions in such factories with reference to the application of electric motors. Twenty to twenty-five barrels of flour are used daily in this factory for the manufacture of sweet biscuits, and about 60 barrels of flour for the manufacture of soda crackers, which are produced at

the rate of 360 per minute. The electric energy is supplied by the local central station at 220 volts, three-phase. The power consumption averages about 3 000 kilowatt-hours per month.

A general idea of the equipment of the factory is obtained by referring to Table 1, from which it may be seen that a total of 120 horse-power in motors is installed. The factory is divided into three departments,—a sweet department, devoted to the manufacture of sweet biscuits; a sponge department, manufacturing soda crackers; and an icing department, where a portion of the sweet products are iced.

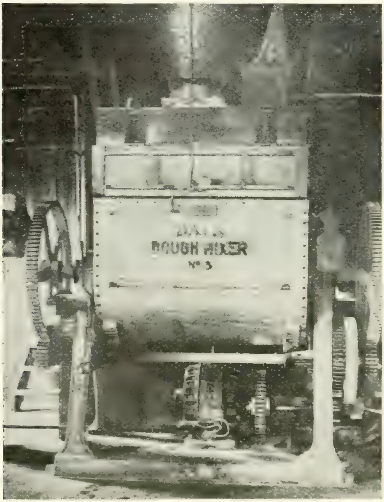

FIG. 1—FIVE BARREL DOUGH MIXER, GEARED TO TEN HORSE-POWER MOTOR

THE SWEET DEPARTMENT

The dough mixers in this department are operated by a single motor, placed on the floor above and belted through that floor to a short line shaft hung above the mixers. The use of the electric motor as a drive for these machines, as well as for the dough mixer in the sponge department is a striking example of that feature of the electric motor which gives it so great favor in so many industries, viz., the ease with which it can be used to drive a single machine or group of machines which must be operated at a time when the rest of the factory is shut down. The regular working day in the factory starts at 7 A. M., but a preliminary run, lasting generally from 2 A. M. until 7 A. M., is required for preparing the sponge and dough for a regular day's run of baking, etc., hence, a separate drive for these machines is particularly advantageous.

A dough mixer requires a comparatively large starting torque

and for that reason, a motor operating it should have ample overload capacity. A typical, five barrel dough-mixer, direct-connected to a 10 horse-power motor is shown in Fig. 1. After mixing, the dough is taken from the mixers and placed in troughs mounted on trucks and is thus transferred to the forming machines. These machines are grouped directly in front of the oven, as shown in Fig. 2, and perform the several operations of rolling the dough to the proper thickness, cutting out the biscuits in the desired shapes and sizes and delivering them to the oven operators for placing in the oven. A single motor, hung from the ceiling, drives this group of machines. The motor is belted to a short line shaft

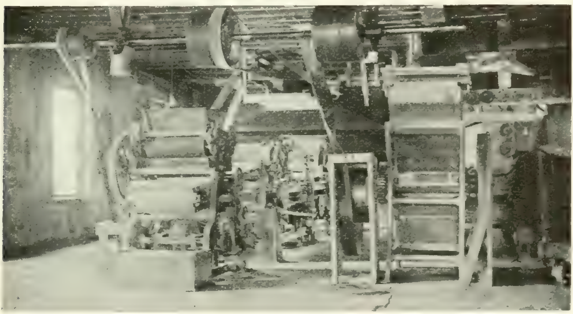

FIG. 2—FORMING MACHINES

through a variable speed transmission and in addition, the machines are provided with change gears.

The oven used in this department is similar to the one in the sponge department, which is shown in the background of Fig. 4. The oven is of the Ferris wheel or rotating type, consisting essentially of a large brick chamber, usually two stories high, in which is a rotating reel supporting two large iron rings, one at each end of the oven. The shelves on which the material to be baked is placed are pivoted to these rings in such a way that they will always remain in a horizontal position as the reel rotates. The oven is provided with a long narrow door at a suitable height from the floor by which the attendants transfer the material into and from the oven. The motor which operates the oven runs continually and is connected to the oven mechanism by a clutch which releases

automatically when the reel has rotated a distance equal to the space between two shelves. Each movement of the reel thus brings a shelf directly in front of the door. It requires an average time of three and one-fifth minutes for the reel to make a complete revolution, that much time being required for baking.

Biscuits are removed from the cutting machines, and placed in the oven on thin sheets of metal by the operators. After a complete revolution of the reel these sheets are removed with their loads of baked biscuits and placed on the trays of special trucks for transferring them to the packing conveyor. In order that all the biscuits baked during any given time, may be packed promptly, the oven operations stop 15 minutes before the work at the packing

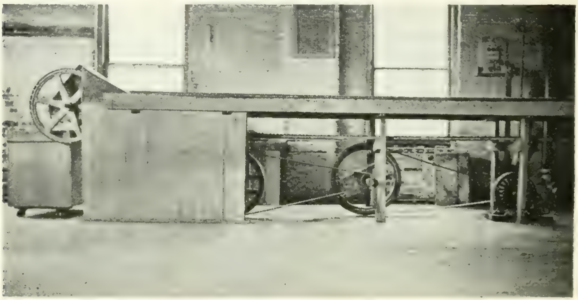

FIG. 3—DRIVE FOR PACKING CONVEYOR

conveyor, a fact which again brings out the superiority of the electric drive for this machinery.

The packing conveyor is essentially a continuous horizontal belt on which the pans of biscuits are placed. The belt moves at the rate of about 17 feet per minute, and the packers standing on both sides, remove the biscuits from the pans and pack them in boxes for the trade. The motor for the conveyor is directly beneath it and is belted down to the proper speed, the great reduction secured being shown by Fig. 3.

THE SPONGE DEPARTMENT

In this department, the process of manufacture is quite similar to that of the sweet department. An idea of the principal machinery used, with the exception of the dough mixer, is given by referring

to Fig. 4. A dough roller, connected to its motor through a chain drive, is shown at the right. This machine gives the dough a preliminary roll before it is placed in the cutting machine (shown

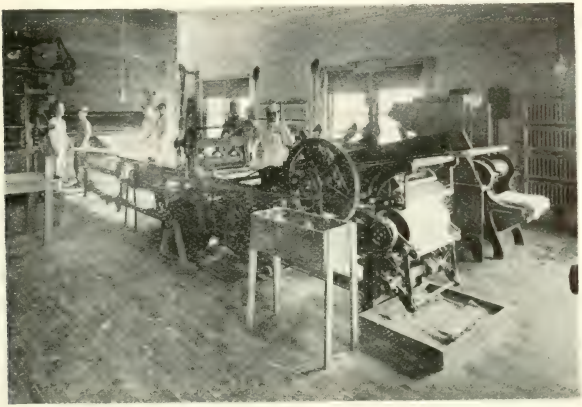

FIG. 4—DOUGH ROLLER AND CUTTING MACHINE

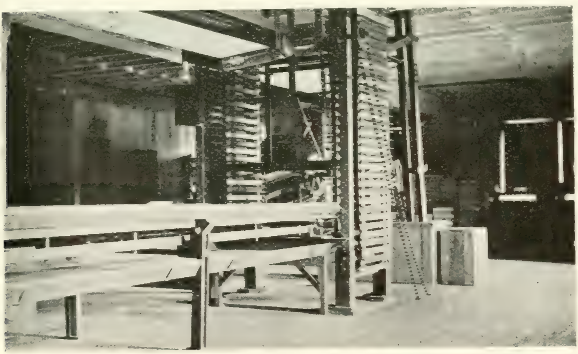

FIG. 5—PAN TOWER AND PART OF PACKING CONVEYOR

in the foreground) which rolls it to the desired thickness, and stamps out the soda crackers. The cutting machine is connected through a variable speed transmission and a chain drive to a motor hung from the ceiling underneath.

Soda crackers are conveyed as fast as they are baked by means of a pan tower, shown at the left of Fig. 4, to a packing room, two floors below. From the packing room the empty pans are carried back to the oven by the same tower. This pan tower consists of two belt conveyors with the pans placed on angle iron projections and suspended between the belts, as shown in Fig. 5. The motor is mounted on the frame work at the top of the shaft and is connected through gears to both sides of the conveyor so that they will always run at the same speed. When the pans reach the

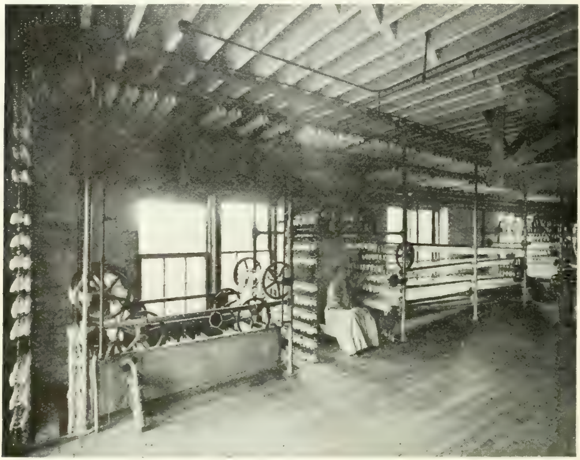

FIG. 6—ICING CONVEYOR

bottom they are delivered to the horizontal part of a second conveyor which carries them along in front of the packers, and then back under the floor and up along the side of the first conveyor to the ovens.

When oyster crackers are manufactured, they are conveyed by a separate belt conveyor to the same packing room. Advantage is here taken of the fact that the oven motor is running continuously and this conveyor is belted through a shaft to this motor.

ICING DEPARTMENT

The icing conveyor used in this department, a view of which is shown in Fig. 6, is one of the most interesting devices in the

factory. It consists essentially of a continuous chain conveyor supporting 431 200 galvanized hooks from which cakes can be suspended. As it moves along it dips the cakes in icing, suspends them while drying, and delivers them to a packer. The conveyor is 860 feet long and moves at a rate of from 200 to 380 feet per hour.

The motor operating this conveyor requires considerable speed reduction, which is obtained in this case through reduction gears. The changes of speed are obtained through a speed variator.

The rest of the machinery used in this department is used in connection with the preparations of special forms of icing given some products. It is all driven from one motor and a short line shaft as shown in Fig. 7.

FIG. 7—ICING ROOM

In addition to using electric drive for the machinery that is directly connected with the manufacturing process of the factory, a five horse-power motor is used for driving two box-nailing machines and two ten horse-power motors for operating two elevators, while a five horse-power motor, with buffing wheels mounted on each end of the shaft, is used for polishing the tin boxes in which a part of the product is packed.

SPEED REQUIREMENTS

An installation of this character is of interest on account of the simultaneous requirement for wide speed variations, and for induction motor drive. The necessity of variable speed for the cutting machines arises principally from three sources, viz: different sizes and shapes of biscuits, different kinds of dough, and different

times required for baking. A "sticky" dough requires a different speed of cutting for satisfactory results than does a dry, stiff dough. In general small biscuits can be cut more rapidly than large ones; for instance, in the sponge department, the variable speed shaft can be run between the speeds of 30 and 125 r.p.m. for soda crackers, and between 110 and 200 r.p.m. for oyster crackers. The average time for baking in the sweet department has been given as three minutes and twelve seconds. With the same oven temperature, some biscuits require less and some more time than this for baking, hence the reel of the oven must be rotated slower or faster, and the speed of the cutting machine changed accordingly.

All of the variable speed transmissions are of the Reeves type, consisting of belts on which are mounted wooden blocks with beveled ends, running between special pulleys, each of which consists of two conical faces with the apexes facing. By changing the separation of the cones, the effective diameters of the pulleys can be varied over a wide range, giving close speed control. Where the speed range thus secured is not sufficient, special gears are used.

In the sweet department, the speed of the cutting machines is changed six or seven times an hour on the average, the speeds of the cutting machine, and the soft dough cutting machine being controlled in common by a single speed regulator, while the speeds of the press and dough roller are varied by changing gears. This latter change in speed is not required often. In the sponge department, the speeds are changed once or twice a day on the average. The speed of the icing conveyor is usually changed three or four times a day, the reason for this change being that it requires less time for some forms of icing to harden than it does for others.

GROUPING OF CURRENT TRANSFORMERS

REVERSED-V AND Y-CONNECTIONS

HAROLD W. BROWN

THERE are in common use five different ways of grouping the secondaries of current transformers on three-phase circuits. They may be distinguished according to the following definitions. As indicated in Fig. 1, there are alternative methods of making these connections. For example, two methods of making the delta and Y-connections, and three methods of making the reversed-V, open delta, and Z-connections are shown. There are several other alternative ways of making the latter three connections, but as they offer no special advantages over those here given they need not be considered.

The *Reversed-V Connection** requires two transformers. They may be on any two of the three lines. One of the leads from the secondaries is common to the two transformers. It connects to *corresponding* terminals of the secondaries of the two transformers, see Fig. 1. The currents in the three leads differ in phase by 120 degrees, and each differs from two of the line voltages by 30 degrees and from the third voltage by 90 degrees (This may be seen by reference to the vector diagram, Fig. 1, corresponding to this connection). On a *two-phase* circuit, a connection corresponding to the reversed V-connection is the only one that is commonly used. The current in the common lead is 45 degrees out of phase with all of the other currents and voltages.

The *Open Delta or V-Connection* differs from the reversed-V only in that the common lead connects to *non-corresponding* terminals. The current in the common line is in phase with the voltage between the lines to which the transformers are connected.

The *Delta Connection* has three leads from the secondaries of three transformers. Each lead connects to *non-corresponding* terminals of two transformers. The currents in the three leads differ in phase by 120 degrees and each is in phase with the voltage between the two lines to which the two transformers adjoining that lead are connected.

The *Z-Connection* is the same as the delta with one secondary reversed. It has three leads from the secondaries, one of which

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*Called a "V connection" by some authors. The use of the latter term is not consistent with similar usage in referring to power transformers.

connects to *corresponding* terminals of any two transformers. A second lead connects to *corresponding* terminals of another pair of transformers, and the third lead connects to the remaining two terminals, which are *non-corresponding*. The first and second leads connect respectively to two relays or trip coils, and the third is the common return. The current in the third lead is in phase with the voltage between the lines to which the two transformers adjoining that lead are connected. On the other leads, the current in each differs in phase by 90 degrees from the voltage between the two lines involved—in one case leading and in the other, lagging.

The *Y-Connection* also requires three transformers, and each transformer has a separate lead. These three leads are from cor-

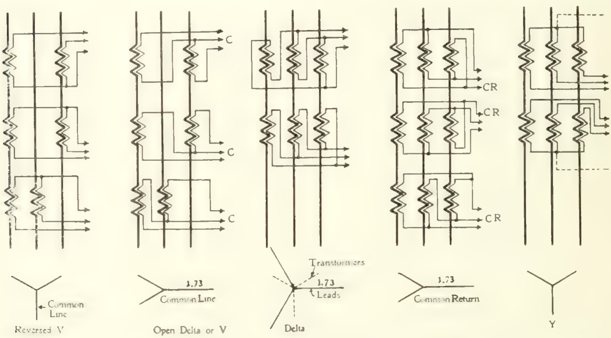

FIG. 1—DIAGRAMS OF CONNECTIONS AND VECTOR DIAGRAMS REPRESENTING VARIOUS METHODS OF GROUPING CURRENT TRANSFORMERS

responding terminals. The remaining three terminals are all connected together, and in some cases a fourth lead is brought out from the common point. The currents and phase relations are the same as in the reversed V-connection.

All of these phase relations are of course on the assumption of 100 percent power-factor and balanced load.

Some of these groupings may be used either with or without change, on single, two, and six-phase circuits. The best arrangement to use depends on the kind of circuit to which the primary is connected, and the apparatus connected to the secondary. There is a standard connection suitable for each kind of apparatus, but this connection may be modified to adapt it for additional apparatus. The most common grouping for use with meters is the two-trans-

former combination, here designated as the "reversed-V" connection, Fig. 2, which is suitable for three-phase three-wire, and two-phase three or four-wire circuits. The combination for use with overload relays, to obtain the best protection for a three-phase circuit is the "Z-connection." But neither of these groups is best adapted for use with voltage compensators and voltage regulating apparatus, which usually have an "open-delta-connection." If meters and relays, or relays and a compensator, or any other combination of apparatus is to be connected to any circuit, it is usually possible to modify the connections so as to avoid supplying an extra set of transformers. In cases like those just cited, the meters may be operated from Z or open-delta-connected transformers, or voltage compensators may be operated from Z or reversed V-connected transformers.* In this and a subsequent paper, the various transformer groupings will be treated with reference to the kinds

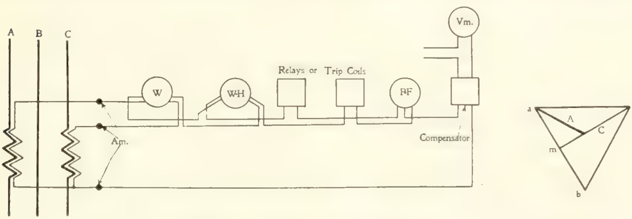

FIG. 2—DIAGRAM OF CONNECTIONS AND CURRENT VECTOR DIAGRAM FOR CURRENT TRANSFORMERS IN REVERSED-V-CONNECTION

of apparatus that can be operated from them, and the relative advantages of the different groupings. Connections to voltage transformers are shown in some cases, to indicate the complete arrangement.

REVERSED-V CONNECTION

The connections of a wattmeter, watt-hour meter, and power-factor meter, together with relays or trip coils, and a compensator or voltage regulating device, are shown in Fig. 2. Ammeters or ammeter receptacles may also be inserted at points marked *Am.* For convenience all the apparatus is shown connected to a single pair of transformers, but this connection is liable to introduce an excessive transformer error, on account of large impedance in the

*Some connections otherwise allowable are impractical on account of the error of transformation, where some of the apparatus has considerable impedance. See "Characteristics of Current Transformers" in the JOURNAL for July, 1911, p. 642.

secondary circuit. At least another pair of transformers would be required for operating all the apparatus indicated in the diagram.

Wattmeter and Watt-hour Meter—These instruments should not be connected in series with the compensator if accurate measurements are desired. Neither should they be connected with circuit-breaker trip coils, or relays, except as the relays have low impedance. (The impedance of overload relays is usually high, but that of some reverse current relays is comparatively low). Wattmeters and watt-hour meters cannot be compensated for transformer errors unless the power-factor of the load they measure is constant.

Ammeters—It is preferable that ammeters shall not be in series with the compensator, if there is one, nor with relays of considerable impedance, although if the impedance is constant and not too large the ammeters may be calibrated to correct for the transformer error.

Power-Factor Meter—This instrument may be in series with any of the other apparatus unless the compensator has a large resistance. Any ordinary reactance has no appreciable effect on the power-factor indication.

Relays or Circuit Breaker Trip Coils—This connection does not offer the best protection to the circuit, because there are transformers in only two lines, so that it is possible to ground the middle line without operating the relays or circuit breaker. If the relays or trip coils are for overload protection, three Z-connected transformers are better. If they are for reverse current protection, three Y-connected transformers are commonly used, with three relays. But if the circuit under consideration is an incoming one that has all three lines protected at the other end, it is considered good practice to provide only two transformers for overload protection at the incoming end.

Voltage Compensator or Voltage Regulating Apparatus—Voltage compensating or regulating apparatus is intended to correct for the line drop in two of the lines (the two lines between which the voltage is measured), so that the voltage indication or regulation will be on the basis of the voltage between these two lines at a distant point. To accomplish this perfectly under all conditions of unbalancing it is necessary to correct for line drop in *both* lines by means of current transformers in both lines (they must then have an open delta instead of a reversed-V connection); but if the load is *balanced* either the connection in Fig. 2 or a single transformer can be used, but the compensation will be 30 degrees from

the right phase relation, except as the proportion of resistance and reactance compensation is varied so as to shift the phase of the total compensation and correct for the 30 degrees discrepancy. This phase relation is illustrated in Fig. 2, where the lines marked with large letters, *A* and *C*, represent the phases of the currents in the two current transformers and the lines marked with small letters *ba* and *bc* represent the voltages, which are 30 degrees out of phase with the two currents. If the load is unbalanced, it is more accurate to correct the three voltages independently, by means of three voltage compensators, but this is usually considered an unnecessary refinement.

Where only one current transformer is used, if two voltage transformers are available and a lead can be brought out from the middle point of one of them, the current and voltage may be brought into phase with each other, as in Fig. 3. The voltage connection of the compensator is from the middle of one transformer to the end of the other. The voltage is represented by the line *mc* in Fig. 2, which is exactly in phase with the current *C*. It is not necessary to make the 30 degree correction mentioned above by varying the proportion of resistance and reactance compensation, but the voltmeter must be specially calibrated so as to indicate full voltage when it actually has only 86.6 percent of full voltage. Furthermore, the voltmeter does not indicate the voltage between two of the lines, but a combination of two voltages. This is not necessarily a serious disadvantage, especially if all three of the voltages are about the same. In Figs. 2 and 3, for purpose of simplicity, only a voltage compensator is shown. It may be replaced by any other apparatus correcting for line drop.

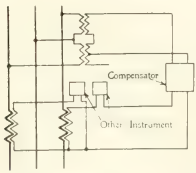

FIG. 3—COMPENSATOR WITH REVERSED V-CONNECTION OF CURRENT TRANSFORMERS

Y-CONNECTION

The Y-connection is not so common as the one just considered, because it requires an extra transformer, and there is usually not sufficient advantage gained to warrant it. Where it is used it should be for some special purpose. The following are among the most common cases where a Y-connection is desirable.

1—All of the apparatus shown in Fig. 4 is essentially the same as in Fig. 2, with the addition of one relay which is connected in

series with the additional current transformer. This is a common method of connecting reverse current relays for the protection of all three lines. It may be used similarly with overload relays, but the Z-connection is preferable for overload in that it requires only two instead of three relays. Three ammeters may be connected as indicated at the left, or for a three-phase three-wire circuit the middle ammeter may be replaced by the one at the right, in the middle line of the power-factor meter. These connections are suitable for either three-wire or four-wire three-phase circuits, except that current in the neutral line introduces errors in the wattmeter, watt-hour meter and power-factor meter, and in the ammeter at the right.

2—The equivalent of a Y-connection is sometimes used where one instrument (which may have a high impedance) is to be con-

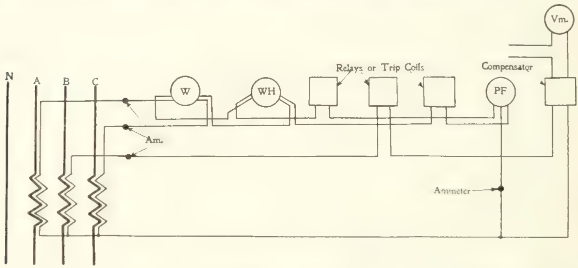

FIG. 4—Y-CONNECTION FOR OPERATING THREE RELAYS AND OTHER APPARATUS ON THREE OR FOUR-WIRE CIRCUIT

nected to one transformer and the other transformers are used as in Fig. 2, and are not subject to the errors of the third transformer. The third transformer in reality has nothing to do with the other two, except for its location and the fact that it has the same ground return. These connections are indicated in Fig. 5.

3—The current transformer error is less as the voltage across its secondary is decreased. On this account a third transformer may be added to furnish a part of the voltage. The voltage of each transformer is thus reduced, and the ratio is correspondingly decreased. Connections are as in Fig. 6.

4—On three-phase four-wire circuits three Y-connected transformers are sometimes used with ammeters. Other apparatus used for controlling or making measurements on individual lines may be similarly connected. The reason for this connection rather than

the reversed-V is that the current in the middle line is liable to be different from the resultant of the two outside lines (which resultant would be measured with a reversed-V connection). A four-wire circuit is different from a three-wire circuit in this respect. Fig. 7 shows connections of ammeters and other apparatus on a three-phase four-wire circuit. Other combinations of three transformers are used for this purpose more frequently than the Y-con-

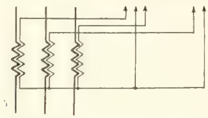

FIG. 5 — Y-CONNECTION TO SEPARATE APPARATUS OF HIGH AND LOW IMPEDANCE

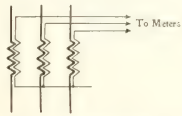

FIG. 6—Y-CONNECTION TO REDUCE TRANSFORMER ERROR

nection. They will be mentioned in a subsequent paper, dealing with open-delta, delta, and Z-connections.

DOUBLE-REVERSED-V AND Y-CONNECTIONS ON SIX-PHASE CIRCUITS

A six-phase rotary converter ordinarily receives its power from a bank of three power transformers. There are three cases to consider with reference to the grouping of current transformers:—

Current Transformers in High-Tension Circuits—The high-tension circuit is ordinarily a three-phase three or four-wire cir-

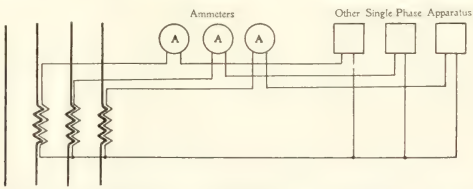

FIG. 7—Y-CONNECTION TO AMMETERS AND OTHER APPARATUS ON THREE-PHASE, FOUR-WIRE CIRCUIT

cuit, and current transformers on the high-tension side have the same connections as on any other three-phase circuit. The corresponding voltage transformer connections should be made to the high-tension side unless it is allowable to have a phase error of a few degrees due to the reactance drop in the power transformers. Neglecting this error, low-tension voltages may be obtained that are in phase with the high-tension voltages between lines or from line

to ground. The pairs of leads in Fig. 8 (a) to (d) are marked to indicate the high-tension voltages with which they are in phase.

Current Transformers in Double-Delta Low-Tension Circuit—Where the power transformer secondaries are double-delta connected, each delta is distinct and could have its own current and voltage transformers, but the voltages are so nearly balanced that

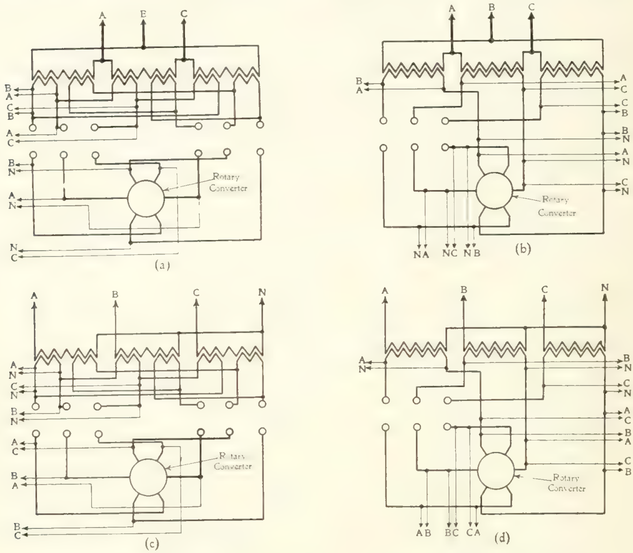

FIG. 8—LOW-TENSION LEADS IN PHASE WITH HIGH-TENSION LINES

a—Delta to double delta power transformers
b—Delta to diametrical power transformers
c—Y to double delta power transformers
d—Y to diametrical power transformers
A, B, C and *N* indicate the three phases and neutral.

the extra pair of voltage transformers is unnecessary. Also, if the rotary converter is well balanced, it is not always necessary to have the extra current transformers, because the currents in the two deltas will be very nearly the same. Where the extra current transformers are provided, they may be connected as in Fig. 9 if the apparatus to which the secondaries connect has a large enough current capacity.

Current Transformers in Diametrical Low-Tension Circuit—Each power transformer secondary is in a separate circuit. If the load is unbalanced it is necessary to have a current transformer in each transformer circuit. The three current transformers should have a Y-connection, or some other connection suitable for a three-

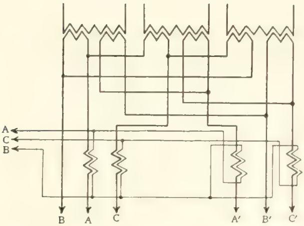

FIG. 9—DOUBLE REVERSED V-CONNECTED CURRENT TRANSFORMERS ON DOUBLE DELTA CONNECTED POWER TRANSFORMER CIRCUIT

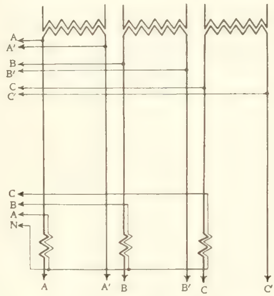

FIG. 10 — Y-CONNECTED CURRENT TRANSFORMERS ON DIAMETRICALLY CONNECTED POWER TRANSFORMER CIRCUIT

phase four-wire circuit, because this is similar to a four-wire circuit in its operation. For a wattmeter or power-factor meter the phase relations of the voltage transformers should be as on a three-phase four-wire circuit. The connections $A\,A'$, $B\,B'$, and $C\,C'$ in Fig. 10 have this phase relation.

RELATION OF WHEEL BASE TO RADIUS OF MIINMUM CURVE

GRAHAM BRIGHT

IN the railway and industrial locomotive field it is often desirable to ascertain quickly the minimum curve that a locomotive or car with a certain rigid wheel base can negotiate, or the maximum wheel base that can negotiate a given curve.

There are a number of different formulæ that can be used to determine these values, but all require more or less calculation and time. The set of curves shown in Fig. 1 make it possible to

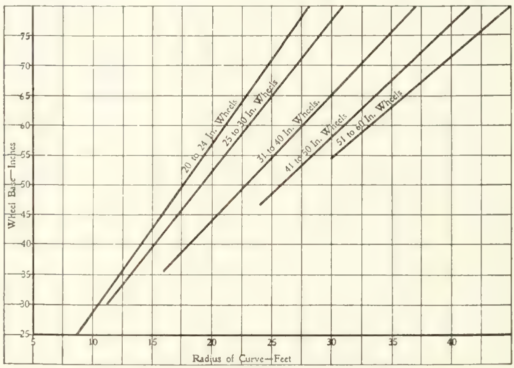

FIG. I—MINIMUM RADIUS OF CURVATURE WHICH CAN BE NEGOTIATED BY RIGID WHEEL BASES OF VARIOUS LENGTHS

obtain directly the information desired.* The values given are for standard wheel, flange and truck play. In order that the curves shall gives results on the safe side, the same gauge is assumed on the curve as on the tangent track. If the track is so constructed at curves that liberal spread is allowed, the values given for wheel base may be increased from 10 to 25 percent.

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*The basis on which these curves are drawn up is from the following information given in a handbook entitled "Locomotive Data" issued by the Baldwin Locomotive Works:

$$R = W \div (2 \sin a)$$

in which R = Radius, in feet, of sharpest curve that can be passed, W = Wheel base in feet, a = Angle which flanged wheels make with the rail.

Wheels 20 in. to 24 in. diameter sin a = 0.117
" 25 in. to 30 in. " " " = 0.107
" 31 in. to 40 in. " " " = 0.090
" 41 in. to 50 in. " " " = 0.080
" 51 in. to 60 in. " " " = 0.075

EXPERIENCE ON THE ROAD.

LEONARD WORK

WHEN exciter generators are to be controlled by a Tirrill voltage regulator, it is necessary, in order to secure an equal division of load when operating in parallel, that their regulation characteristics be similar. Compound-wound exciters of diverse capacities and of various makes, are apt to show different regulation characteristics, and satisfactory parallel operation requires that such differences be harmonized. This is usually accomplished by adjusting the compounding of the machines, the amount of adjustment required being indicated from curves of voltage variation obtained under different loads.

Instances now and then arise where considerable difficulty is encountered in making two or more generators parallel properly, and where no amount of alteration of compounding or adjustment of the auxiliary rheostat supplied in voltage regulator installations is able to bring about the desired result. A noteworthy case of this kind occurred recently where a voltage-regulator was installed to control two 22.5 kilowatt compound-wound exciters. Both were of the same size and make, and apparently were exact duplicates. When these machines were connected to the regulator and in parallel under an equally divided load, the division being effected by auxiliary rheostat adjustment, any increase of load called for by the regulator invariably caused No. 2 exciter to take the increase and No. 1 to lose a small amount of load. This seemed to indicate beyond all doubt an excess of compounding on No. 2, or a lack of it on No. 1, notwithstanding the fact that the regulation curves of the exciters were very similar.

In this plant the voltage requirements were such that the series windings on the machines could not, as a probable means of removing the trouble, be dispensed with. It was therefore decided to decrease the compounding of No. 2 exciter. This was not done by shortening the shunt across the series winding but by introducing resistance in series with the series winding, inside the shunt connection. Incidently it may be mentioned that a point often overlooked in the adjustment of direct-current machines for parallel operation, is that an alteration of the shunt of one machine also affects the machine with which it is coupled, since, owing to the presence of the equalizer, the resistance shunts and the series

windings of both machines are all in parallel. Therefore, to decrease the compounding of one of a pair of generators by shortening its shunt is to similarly decrease the compounding of the other. In cases where it has been particularly difficult to make the regulation of two machines similar, success has been obtained only by the introduction of resistance, in series with the series winding of the one having the greater compounding, inside its shunt, thus decreasing the current in the series coils.

After the addition of resistance to the series windings of this generator, its compounding was observed to be greatly reduced, and a re-setting of the auxiliary rheostat was required to balance the loads. However, contrary to all predictions, upon a demand for more current at the exciter bus-bars No. 2 still manifested as strong a tendency as ever to monopolize the load. A further reduction in the compounding of this machine availed nothing. This paradoxical result was hardly anticipated but obviously indicated the futility of any further pursuit along these lines.

Attention was next directed to tightening up uncertain contacts in the equalizer connections and to securing an accurate brush setting, which on No. 2 generator was found to be considerably behind the neutral. These latter adjustments caused a slight improvement in conditions: No. 1 exciter instead of losing current as formerly, upon an increase of bus-bar load was now very reluctantly inclined to follow the lead of its companion.

The conditions at this stage were as follows:—Starting with 50 amperes on each exciter, if an increase in load caused No. 2 to assume 90 amperes, No. 1 took only 60. If a light load caused No. 2 to drop to 10, No. 1 would still have 40 amperes. It was clear that when No. 1 machine was given a certain load it was loath to part with it or to accept more while in parallel with the more sensitive unit. It was apparently very sluggish or slow to respond to variations of its own field current. The saturation curve of the sluggish machine showed that it required a considerable variation of the field current to lower or raise the voltage at any point on the curve.

The trail of investigation now turned to the air-gaps of the generators in question and disclosed the fact that the clearance between armature and field poles was much less in one of the machines than in the other. The matter was soon remedied by changing the air-gap by readjustment of liners. After this ad-

justment was completed the machines were again started up and each machine found to operate properly when running alone.

The machines were again connected in parallel and under control of the regulator. A few minutes observation sufficed to prove that the trouble had been eliminated. The No. 1 machine indicated through its ammeter its responsiveness to all load variations, the difference in load between the two being so slight as to be negligible.

AN INDUCTION MOTOR WITH TWO-PHASE—THREE-PHASE CONNECTION

D. C. McKEEHAN

THE difficulty arising in changing ordinary two-phase induction motors to three-phase is that the required three-phase voltage is usually out of range of those found in common practice. Thus, in investigating the matter of changing a certain 50 horse-power induction motor from 220 volts two-phase to 440 volts three-phase, the voltages suitable for delta or star connection of the primary were found to be 320 and 550 respectively, while the only available supply was 440 volts. The motor was of a somewhat obsolete type, with revolving primary and wave wound secondary (stator). It was started by closing the line switch and, after attaining full speed, short-circuiting the stator, as shown in Fig. 1*a*. The original winding consisted of six coils per group, each phase being connected in two parallel circuits of four groups in series, i.e., 96 coils in all.

To adapt this motor for operation on the three-phase, 440 volt circuit available without altering its operating speed, the following changes were made:—In the primary phase *A*, Fig. 1*b* the two groups (48 coils) were connected in series, the ends being connected to the line. In phase *B*, the groups were connected in series, but one coil of each pole was omitted from circuit. These idle coils were left in the slots, however, in order to maintain mechanical balance of the rotor. One end of this phase was connected to the line and the other end to the middle point of phase *A*. The

method involves no new idea, as it is simply an application of the familiar three-phase—two-phase transformation scheme to an induction motor. The success of the arrangement meant a saving of two transformers besides uniformity of apparatus as regards voltage. It is applicable in cases where the two-phase motor is liberally rated, as the starting torque and maximum torque will be

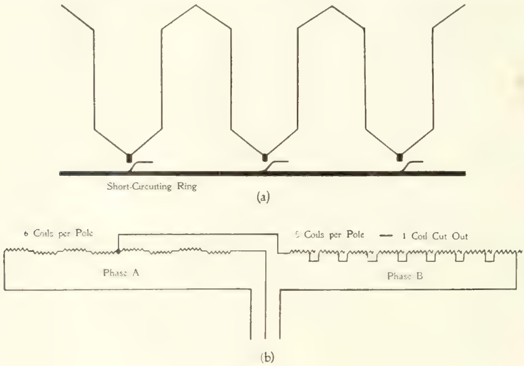


FIG. 1

reduced considerably and the temperature rise at full load when operating as a three-phase motor will be about 35 percent greater than as a two-phase machine. The motor in question had been in service for some fifteen years, and continues to operate satisfactorily with the three-phase connections.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

631—Pitting of Generator Collector Rings—We have a number of 4000 and 2000 kw, 6000 volt alternating-current generators which give considerable trouble at the collector rings. The surface of the rings is badly pitted, especially at certain points. What is the cause and how can the rings be cut smooth? C. W. G.

We assume that the generators referred to are revolving field generators and that the collector rings carry the exciting direct current. The most common of the several possible reasons is that the rings and brushes are not kept perfectly clean, and that not enough lubrication is used. Furthermore, there are certain combinations of material in rings and brushes which produce better results than others. A good combination is a cast iron ring and a moderately soft carbon brush. One reason for pitting of collector rings is defective castings. Blow holes may develop after the surface of the ring has been worn. It usually helps to turn the rings down sufficiently to clear out all of the holes in the surface of the rings, to lubricate properly and to be sure that the brushes move freely in the holders and have the right tension. J.B.-W.

632—Principle of Design of Ammeters and Voltmeters — Does the ammeter differ from the voltmeter only in the size of cross-section of the wires used in its manufacture or how? Please explain. J. L. C.

Voltmeters are made on the same principle as ammeters. They have a much larger number of turns of wire in the winding, and small sized wire is used. The voltmeter reading is dependent upon the amperes in its winding. Therefore a voltmeter may be considered as a low-reading ammeter in which the scale is marked to read the voltage required to pass sufficient current through the coils to give a certain deflection. Nearly all voltmeters contain resistance coils in series with the operating coils, for the purpose of keeping the current down to a very small amount. H. B. T.

633—Effect of Opening Field of Alternator—What would be the effect of tripping the field on a 2000 kw three-phase turbo-generator operating in parallel with others? What would be the effect of immediately replacing it? G. M. D.

The generator may or may not drop out of step, depending upon the load which it is carrying and upon its inherent synchronizing ability. If operating at full-load, it will probably drop out of step. If so, replacing the field will not correct the trouble. In that case it will be necessary to disconnect the generator from the line and re-synchronize it. If the generator does not drop out of step the field can be replaced and normal conditions secured without disconnecting the generator from the line. E. M. O.

634—Emergency Connection for Delta-Star Transformers — Current is generated in a power-house at 2200 volts and stepped up by means of three single-phase transformers (primaries connected delta, secondaries in Y with the neutral grounded), to the transmission voltage, 60000 volts. There are four sub-stations on this line, and the transformers are connected primary star with neutral grounded, and with the secondaries in delta. In case one of the transformers at the power house should burn out, what would be the proper way to connect the other

two, to save changing those in the sub-stations, which is almost impossible. G. M. D.

The burnt out transformer should be removed from the circuit and the conductor of the transmission line thereby left inactive should be connected to the neutral point of the high-tension side of each of the substation groups and to the common point of the high-tension windings of the two remaining power house transformers. The neutral points may or may not be left grounded. It is better to have them ungrounded under these conditions, otherwise telephone disturbances are likely to arise. The capacity of each of the sub-station groups, with a load of given power-factor, is reduced to 57 percent of the rated capacity. The two power house transformers will deliver 86 percent of the capacity of the transformers remaining in service. The line connected to the neutral points will carry a current in value approximately 73 percent higher than the current in each of the other two lines. C. F.

635—Stresses in Transmission Line Wires—In a transmission line with "A" frame steel towers about 400 feet apart, is there any objection to so stringing the six copper wires (two three-phase lines) that in cold weather they will be stressed beyond the elastic limit, yet with a factor of safety such that the stress will be one-half the ultimate strength at 20 degrees below zero. A. L. M.

Copper wires having an ultimate tensile strength of approximately 30 000 to 40 000 pounds per square inch and an elastic limit of about 15 000 pounds are probably referred to. As a general proposition, a factor of safety of two is not sufficient for conductors of low tensile strength. If cables having high tensile strength were involved, such a safety factor would probably prove satisfactory, provided the cables were so strung as to allow for their contraction at times when the temperature approached 20 degrees below zero. It will be seen that if the lines were installed with a tension approaching the elastic limit of the material under condition of summer temperatures, the contraction resulting from the lower temperatures of winter might be sufficient to strain the conductors beyond their ultimate tensile strength. Moreover, if the question were based on the assumption that the stresses were to be calculated as occurring in still air, and the lines were stressed beyond their elastic limit and up to one-half of their ultimate tensile strength with the temperature at 20 degrees below zero, the wires would be liable to break in case of a severe wind storm, particularly if the wires were coated with sleet. Probably little trouble would be experienced with the towers, so long as the line wires did not break, for, in a properly designed and carefully constructed transmission line, there will be equal strains in opposite direction along the line. S. Q. H. & C. H. S.

636—Power-Factor Curve of Induction Motor—What would be considered a good power-factor curve from no-load to full-load on a 100 hp, two-phase, 220 volt, 450 r.p.m. induction motor. G. H. S.

The following would be a good power-factor curve:—

Motor	Squirrel Cage.	Slip Ring.
0	0.15	0.12
1/4	0.57	0.52
1/2	0.77	0.73
3/4	0.85	0.82
Full Load	0.88	0.86

H. L. B.

637—Distribution System for Steel Plant—A steel company is about to make use of the three-phase—two-phase connection for transforming from 13 200 volts three-phase to 220 volts two-phase. The service is for motor and lighting purposes, the load varying from 50 kw to 500 kw. Would this system be practicable in this case? What trouble is most likely to occur? Would it be satisfactory to change from 13 200 volts to 220 volts and operate the mill at this voltage? Is there any danger as regards fire risk, etc. What protection would you recommend? G. H. S.

The system you propose is practicable if the horse-power of the largest motors is not too large for a 220 volt design. The only serious objection to a low voltage system for

motor circuits is that it takes a comparatively large current for a small amount of power, and the line drop on the distributing system may be troublesome. There should be no difficulty in transforming from 13 200 volts to 220 volts and operating the mill at 220 volts. There should be no more fire risk in this case than at other voltages. The wiring should, of course, be installed in accordance with the rules of the National Board of Fire Underwriters. The most desirable protection would depend on local conditions. A circuit breaker, auto-starter or overload relay, with an inverse time limit would be desirable on at least the larger motors.
H. W. B.

638—Three-Phase Power with One Single-Phase Wattmeter—When measuring the power supplied to a perfectly balanced three-phase delta-connected induction motor, is it possible to use a single-phase wattmeter, using only one voltage and one current transformer as shown on the sketch Fig. 638 (a)?
G. .H C.

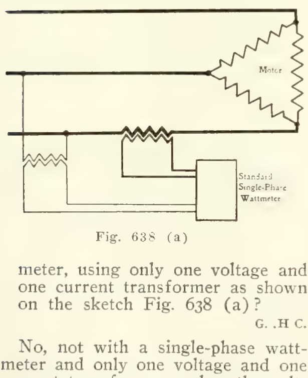


Fig. 638 (a)

No, not with a single-phase wattmeter and only one voltage and one current transformer, unless the voltage transformer can be connected to the neutral point of the system. With the connection shown, the correction factor is different at different power-factors.
H. W. B.

639—Highest Voltage Direct-Current Generator—What is the highest voltage direct-current dynamo ever built that you have record of?
W.J.P.

A 25 000 volt direct-current generator was built by M. Thury for testing purposes. Its approximate rating was 25 kw, one ampere. This machine was of the revolving field type, the field current being introduced by means of collector rings and brushes. The commutator was operated at about 500 average volts per segment. Condensers were connected in shunt across adjacent commutator bars. This machine probably had constant current characteristics which permitted much higher voltage per bar than is permissible with constant potential machines.
F.I.H.

640—Varnished Cambric—How is the insulating material known as "varnished cambric" made? Is it a secret process?
W.J.P.

Varnished cambric consists usually of a special grade of cambric coated on both sides with two or three coats of a baking varnish. This coating is put on either by stretching the cambric to be treated on frames and dipping in a vat of varnish, allowing to drain and then baking in a properly heated oven, or by a tower method in which the process of dipping and drying each successive coat is made continuous. The details of the process are usually kept more or less secret by the manufacturers, but in the main the process is essentially the same. The difference in grade depends on the grade of cambric used, the quality of the varnish, and the skill with which the coating and baking are accomplished. For further information see article by Mr. R. H. Arnold on "Insulating Materials," in the JOURNAL for Feb., 1911, p. 197.
C.E.S.

641—Grouping of Meter Transformers on Three-Phase Circuit—When measuring the power supplied to a perfectly balanced three-phase delta-connected induction motor by means of the single wattmeter method, using three voltage transformers and one current transformer, can the high potential side of the transformers be connected in delta and the low-tension side in star, or must the high-tension be connected in star the same as the secondaries? Also, is it possible to use two voltage transformers on open delta primary in place of the three above mentioned? Kindly give sketches and the ratios of the wattmeter to the

power irrespective of the ratio of the various transformers.

G. H. C.

Assuming that the voltages as well as the currents are balanced, the primaries of the transformers may be connected in delta and the secondaries in star, as in Fig. 641 (a), but the third transformer is of no value in this case. Transformer No. 3 may be omitted without affecting the results. Fig. 641 (a) would then be equivalent to the diagram Fig. 9 of the article on "Meter and Relay Connections" in the JOURNAL for January, 1909, p. 47. Fig. 8 of the same article shows another method for obtaining the same readings by the use of two current transformers and one voltage transformer. If the primaries are connected in star, the common

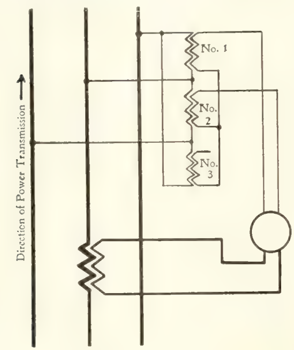


Fig. 641 (a)

point of the three transformers will not be a true neutral, and a considerable error will result, unless the magnetizing currents of the three transformers are the same. Transformers that are to be used in this way should first be tested in parallel, to see that each takes the same magnetizing current at the same voltage. An ordinary open delta connection is not suitable for this use. When the primaries and secondaries of the voltage transformers are star-connected, assuming a 1-to-1 ratio of all transformers, the wattmeter reading must be multiplied by 3 to obtain the total power transmitted over the three lines. In all other cases mentioned above the wattmeter indicates the total three-phase power, *without* multiplying by 3. H. W. B.

642—Test of 800 Ampere Direct-Current Wattmeter—An 800 ampere, 250 volt direct-current wattmeter is to be calibrated. It is connected on a circuit having a very badly fluctuating load (elevator). Does any company put on the market a portable rotating standard which would be applicable to such a capacity? Would it be feasible to use a generator located at the station by running the engine slow and putting its series coils in circuit with the current coils of the wattmeter? This would of course necessitate disconnecting the wattmeter, but can you suggest a better scheme? Up to 300 amperes, a water barrel rheostat load is satisfactory, but above that it is an inconvenient and slow method. I have no duplicate meter to put in series with the meter under test. F. G. F.

We know of no portable rotating standard meter for use on 800 amperes direct-current. A generator can be used in the manner mentioned. It could also be run at full speed with low excitation and the wattmeter connected with ammeter in series across the terminals. A separate source of potential would of course be necessary for either of these schemes, in order to excite the voltage coil of the wattmeter.

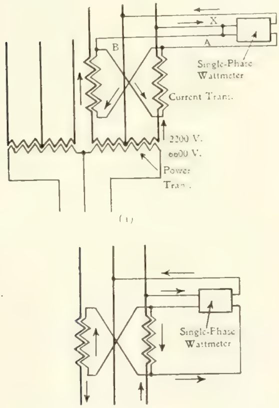
A. W. C.

643—Converter Operated as a Synchronous Motor—Would a single-phase rotary converter give mechanical power in the same amount as a single-phase motor of like capacity, provided there were no direct current taken off the commutator end? If not, what proportion of its capacity would it give? W.J.P.

A rotary converter, if properly designed to operate as a single-phase converter, ought to operate as a motor, giving mechanical loads up to the amount at which it carries load when operated as a rotary converter, providing the construction of the converter is such that it will be able to take care of mechanical loads.

The power-factor will probably be very low. It would be preferable to raise the brushes from the commutator of the machine in case it was operated as a motor. J.B.W.

644—Current Transformer Connections—Some time ago I was sent out to look over the connections to a few wattmeters; the single-phase meters were connected to the current transformers as shown in Fig. 644 (a). Have I shown the arrows correctly in the connections used? Does the wire *A* carry twice the current of wire *B*? Of late I have seen a connection made between the in-going sides of the voltage and current coils as shown by the wire *X*. Does it protect the current transformer from the resulting kick should the circuit be accidentally opened at the meter; if so, how is the circuit made complete? I have heard many different explanation for the use of this tie wire, but none that seem satisfactory. F. G. F.



Figs. 644 (a) and (b)

The arrows showing direction of currents are not correct, as no current would flow through the current coil of the meter. The correct directions are shown in Fig. 644 (b). In some cases, on high voltage circuits, it is desirable to make a connection between shunt and series coils as shown by wire *X*, in order to eliminate any electro-static effect between the two elements in the meter. The tie does not protect the series transformers in the manner suggested. A. W. C.

645—Unbalancing of Phases on Power Transformer—Two 100 kw, 13 000 to 400 volt, 25 cycle power transformers are connected in open delta on both high and low-tension sides. The secondaries are connected to a constant speed Y-connected induction motor rated at 225 hp, 400 volts, 25 cycles, full speed 480 r.p.m. Series transformers are placed in the middle and outside secondary leads of the transformers, and ammeters connected thereto show a smaller current in the middle than in the outside wires by approximately 25 percent. Is this as it should be? Please indicate the relative values of current in both the primary and secondary leads of the transformers when a power-factor of 50 to 100 percent obtains and from no-load to 150 percent load. F.H.C.

The current in the middle lead of a V-connected bank of transformers, with equal voltage impressed on all three phases of the primary side, should be slightly more than the current in the outside leads on account of the fact that the drop in voltage across the open phase of the bank is greater than across the closed phases; this difference in voltage between open and closed phases increases with decrease in power-factor. The unequal current in the present case must be due to unequal impressed voltages on the primary side, or some other cause not within the transformer. The ratio of current in the primary and secondary sides of the transformers at any power-factor and load is inversely proportional to the ratio of turns, and the ratio of turns is equal to the ratio of voltages. The current is equal to load in kw $\div$ 1.73 $\times$ voltage $\times$ power-factor. J.F.P.

646 — Three-Phase Power-Factor with two Wattmeters—*a*—Please advice if the following formula for finding the power-factor of a three-phase circuit from the readings of the two wattmeters used to measure the power is an accurate one and

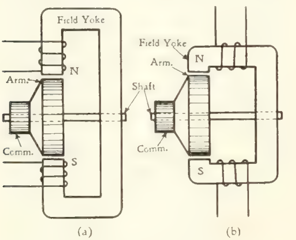
also if this holds for unbalanced circuits?

$$\tan\theta = \frac{\sqrt{3}(W_1 - W_2)}{W_1 + W_2}$$, from which

$\cos\theta$ is obtained. *b*—What would be the resultant power-factor of a delta-connected three-phase receiving circuit when the power-factors of the respective loads are 100, 70, and 60 percent? E.C.E.

a—This formula is correct for balanced but not for unbalanced circuits. Note Nos. 67, May, 1908; 193, Jan., 1909; 364, Jan., 1910; 452, June, 1910. *b*—A diagram should be furnished or a more complete explanation given of the arrangement of circuits, *e.g.*, it should be stated what component of the load is at 100 percent power-factor, what at 70, etc., and through what circuits currents flow. H.W.B.

647—Effect of Shape of Yoke on Magnetic Leakage—In the sketches, Figs. 647 (a) and (b), which of the two field yokes would give the best results? Which would have the less magnetic leakage? cross sectional dimensions of iron are the same—in both cases. W.J.P.



Figs. 647 (a) and (b)

A field yoke giving a long shallow magnetic circuit such as shown in Fig. 647 (a) would have the smallest magnetic leakage as far as the effective armature flux is concerned. The question as to which is the better form to employ in a given case is one depending chiefly upon the structural convenience, etc. F.I.H.

648—Induction motor changed from Internal to External Resistance Type—We have several General Electric induction motors, three-phase, wound secondary type, for 60 cycles, 440 volts, and from 50-150 hp. capacity, fitted with internal secondary resistance for starting, which is cut out by brushes actuated by a rod through the hollow shaft. They are used in dusty places under heavy starting conditions, which results in the brushes and copper resistance bars burning out. I propose to take out all of these internal resistances, brushes and all; on the end of the hollow shaft to screw a hollow stud, fastening on it three insulated collector rings, with their brush rigging; through the hollow shaft lead the conductors, connecting them to their respective rings, placing outside resistance connected in star between the brushes for starting purposes. What size of secondary wires will be required for a 100 hp motor? The hole in the shaft is only one inch in diameter, which is not large enough to contain cables of the cross-section of the three present internal connections. What voltage and amperage will the secondaries be subjected to at starting and at full speed? F.P.

This is probably an old type of motor in which the voltage across the internal resistances was designed to be as small as possible, and consequently with high current. We would suggest that the armature be reconnected internally from two-circuit "Y" to one circuit "Y", and that the shaft be drilled to have a 1¾ inch diameter bore in order to bring out leads of sufficient size to carry the current. If the armature is reconnected, the current in the line would be about 140 amperes which would require 144 000 circ. mils. The voltage between rings would be 236. We would suggest that a resistance of 0.97 ohms for full-load starting torque be used. H.G.R.

649—Two Transformers on Three-Phase, Three-Wire vs. Four Wire Circuit—Would two single-phase standard transformers connected to a 400 volt, four-wire, three-phase Y connected primary circuit as explained in question 453, June, 1910, be as satisfactory in operation as two single-phase units connected to a 2 300 volt, three-phase delta primary with secondaries V-connected? *a*—What would

result if the neutral primary should break between transformers and station? *b*—If one secondary should become open? *c*—If, with three units, delta secondary, carrying lights and power, one unit were more heavily loaded than the other two and the neutral should break, what would result? *d*—Would there be dangerous conditions caused by any of the above? *e*—If, with three units, one secondary became open-circuited, what would result? C.A.D.

Two single-phase transformers connected as in No. 453, will operate as satisfactorily as two transformers connected in V. *a*—If the neutral between the transformers and station should break, the three-phase relation would be destroyed and the transformers would then operate in series across a single-phase circuit, but owing to the connection of the secondary windings, the voltage between the two outside leads would then become zero, while the voltage between the middle lead and either outside lead would become 58 percent of its original value. *b*—If one secondary should open, the three-phase relation would again be destroyed, cutting one transformer out of service; the remaining transformer would operate single-phase at normal voltage. *c*—With three units having their primaries Y-connected and the neutral brought out, no harm would result if the neutral were opened. *d*—There would be no dangerous conditions caused by any of the above. *e*—With three units connected in Y-delta, or delta-Y, if one of the delta connections should break, there might be a high stress produced across the winding of this transformer on the Y-connected side, due to a large reactance being thrown in series with the line. J.F.P.

650—Insulation Test for 400 Volt Alternating-Current Motor— *a*—What is the best method for testing alternating-current motor for grounds, and short-circuits between phases? *b*—What is the standard test voltage for a 400 volt machine? *c*—What should be the capacity of the testing apparatus? *d*—Is it necessary to connect a spark-gap in the testing circuit? E.F.

a—The usual method for testing alternating-current motors for grounds, and short-circuits between phases is to use a step-up transformer of proper voltage, with a light fuse in the primary circuit, so that when a fault exists, the fuse will blow. *b*—The usual test for new machines is 1 500 to 2 000 volts, depending on the size of the machine. *c*—The American Institute standard makes the division at 10 kw; the capacity of the testing apparatus may be quite small for motors of the average size, one kw transformer being adequate. *d*—For these lower voltages a spark-gap is usually not required. It is not customary to test machines which have been in service at as high a voltage as those which are tested in the factory, for the reason that there is almost invariably an accumulation of dirt on the insulating surfaces, such as to weaken the insulation when a direct break-down test is applie. If the motors will stand a test of twice normal voltage after being in service for some time, this should insure that the insulation is adequate for average work. Unnecessary breakdowns may be caused by testing at high voltages unless every possible precaution is taken to clean the windings thoroughly before such tests are made. C.E.S.

651—High Center of Gravity of Electric Locomotives—In several published descriptions of the Pennsylvania type of electric locomotive, it is stated that the center of gravity is high. The sense in which the statement is made leads to the assumption that high center of gravity is desirable. Is this true? T.R.R.

High center of gravity is desirable in high speed locomotives, on account of the superior riding qualities obtained, less pounding effect on the rails, etc. For complete discussion of this subject see paper given at meeting of *A. I. E. E.*, at Jefferson, N. H., June 28th to July 1st, 1910, by Messrs. N. W. Storer and G. M. Eaton. Also "Mechanical Features of Electric Locomotives" by Mr. G. M. Eaton in the JOURNAL for October, 1910, p. 782. G.B.

652—Air Compressor Drives— What kind of direct-current motors should be used for driving air com-

pressors? Should they be shunt or compound wound? And for alternating current; should they be of the squirrel-cage or slip-ring type? Are air compressors or ice machines successfully started in practice with squirrel-cage motors either against the working pressure or by relieving the pressure through an unloading valve? M.O.S.

Choice of motors for driving air compressors depends upon the method of operating the compressors. If the compressor is stopped and started frequently, depending upon the demand for air, then it is advisable to use a compound-wound motor so as to reduce the starting current. If the compressor is started at infrequent intervals and the governing is arranged for by operating the valves, then a shunt wound motor is preferable as the change in speed between light load and full load which occurs when the inlet valves are lifted will not be appreciable. The first arrangement is generally adopted for small compressors driven by motors up to 15 and 20 hp, and the latter arrangement for larger compressors. There is no particular advantage in having a compound-wound motor when the air delivered is regulated by lifting the inlet valve, because the motor can always be started light. Alternating-current motors of the squirrel-cage type are used for small compressors up to ten hp, which are frequently started and stopped. They are also used for larger sizes when the compressor starts light. Slip ring motors are used where frequent starting and stopping is required for compressors over about ten hp. See No. 466, July, 1911. W

653—Shaft Revolving in Hollow Electro-Magnet—Would a solid shaft revolving inside a hollow direct-current electro-magnet get hot? Assume the shaft not in metallic contact with the magnet. W. J. P.

It is almost impossible to tell with certainty whether the shaft would heat or not unless more explicit data is given. An apparently simple problem like this may become very much complicated by extraneous conditions. It may be stated, however, that a plain metallic shaft without brushes or revolving arms, etc., cannot become heated by rotation in the axis of an electro-magnet, provided the flux paths surrounding all parts of the shaft are symmetrically and equally placed with regard to the shaft. O. S. J.

654—Totalizing Power of Four Circuits on Single Wattmeter—Four 13 000 volt, three-phase cables have the secondaries of their series transformers connected in parallel to a set of totalizing bus-bars. A watt-hour meter, having its series coils connected across the bus-bars, measures the total current from the four sets of transformers. Will this meter give a true indication of the total power on all four cables when the load is unequally divided among them, and when they all have different power-factors? F. H. C.

Except for negligible errors due to slight differences in transformer ratios, the correct power would be indicated on the watt-meter. Consider two main bus-bars; also four circuits as indicated in Fig. 654 (a)

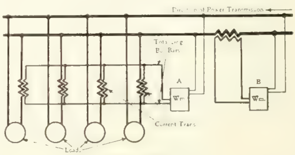


Fig. 654 (a)

corresponding to the four cables described above. Also consider that the four current transformers, one in each circuit, have their secondaries connected in parallel so as to supply the resultant current to the wattmeter at *A*. This is equivalent to the condition described and is obviously equivalent to the second connection for the wattmeter at *B* in which a large current transformer on the main bus-bar is used for feeding the current coil of watt-meter *B* instead of the four separate current transformers, one on each feeder. K. C. R.

CORRECTION

In the Editorial by Mr. N. W. Storer in the October issue, page 821, eighth line, the weight of locomotive should be 130 tons instead of 30 tons as given.

THE ELECTRIC JOURNAL

Vol. VIII DECEMBER, 1911 No. 12

Individual Motors vs. Shafting and Belts

The use of 136 two horse-power motors costing $8 700, individually driving the machines on one floor of a factory, instead of a single 50 horse-power motor, costing $450, seems, at first sight, too absurd to merit second thought. Nevertheless, Mr. Popcke, in his article in the JOURNAL for November, compared individual drive and group drive in a factory where he has made a thorough investigation of the operating conditions, and finds that the first cost of the main shaft, counter-shafts, belts and pulleys, which are necessary for transmitting the power from a large motor to the machines is $8 270, making the cost of the single motor with its necessary auxiliaries within one percent of the cost of 136 small motors. There is, however, an additional allowance for installing the small motors, which brings the total somewhat above that for the single motor equipment. On the other hand, the friction losses in the shaft and belt transmission are so large that the total power required by the single motor costs nearly $1 800 per year more than the power required by the small motors. As this is more than enough to cover the excess in the first cost of the motor equipment for individual drive it would show a handsome saving after the first year. Hence, on a purely cost basis the individual drive is attractive in this case without considering the positive advantages of individual drive in factory operation, which are apt to far outweigh the cost of power equipment.

Another point which impressed me on reading Mr. Popcke's article is the difference between the old and the new methods of handling power. Consider what is involved in getting the power from the engine to the machines it drives by means of belts and jack-shafts on each floor. For clearness of comparison some definite values will be assumed. If they do not commend themselves to the reader, he may insert his own values and modify the conclusions accordingly.

Let the cost of a 300 horse-power engine be $20 per horse-power, or $6 000, and the cost of the belts and pulleys and shafting required to deliver the power to the several floors be equal to the

cost of the belts and pulleys and shafting found necessary for distributing the power on the fourth floor, which was a little over \$8 000. Obviously, if \$8 000 worth of equipment is necessary for getting the power from the engine to the several floors and, say, \$6 000 more is necessary for distributing the power to the machines on each of six floors, the total investment in belts and pulleys and shafts is \$44 000. Again, the test shows a loss in transmission from the engine to the several floors of 32 horse-power at no-load and 75 horse-power at full-load, costing at 1.5 cents per horse-power-hour, from \$1 300 to \$3 100 per year. The friction losses on the several floors aggregates 116 horse-power at no-load. Hence the friction losses at average load are not far from 200 horse-power, which is two-thirds of the engine rating and at 1.5 cents per horse-power-hour amounts to \$8 400 per year. The mechanical transmission in this particular case costs seven times as much as the engine alone, and the power lost is at least two-thirds of that produced and costs each year more than the first cost of the engine.

One is not apt to realize how inadequate are the mechanical methods of power transmission still found in mills and factories until a careful quantitative analysis of the conditions is made. Then one can see why it is cheaper to use hundreds of little motors instead of a few large motors or a big engine, simply on a basis of the cost of supplying each machine with the power it needs.

There is danger in dwelling too minutely on power costs that much more important matters may be overlooked. In the factory in which the foregoing data were obtained it was found that the motors gave an increased speed which increased the output five or six percent where the speed had formerly been low on account of belt slippage in the parts of the factory most remote from the engine. Gain in output and quality, the independence of individually driven machines, the freedom in factory design where there is no shafting, the ease of extension and changes, the better light and air where there are no belts, all these things render the actual cost of power—which is usually only a few percent of the total cost of production—of small consequence compared with the quality of the power. It is this feature which has led many old and established factories to discard their engines—even where much steam is used for heating so that the fuel required for the engines is relatively small—and to drive their machinery by motors and central station power. Is it really better? They have investigated, they have

tried a few motors, they have installed more, they have shut down their engines. That is the best answer to the question whether or not motor drive pays.

CHAS. F. SCOTT

Switchboard Indicating Meters

The switchboard instrument designers have perfected their product to perhaps a higher degree than have the designers of any other switchboard apparatus. To benefit by excellence, the selection of instruments for a particular case must be made with an intelligent appreciation of the characteristics of good meters and of the latest improvements in meters. A number of complete lines of instruments, representing a wide range of characteristics, is now available. The information contained in the article by Mr. Paul MacGahan on "Moderen Tendencies in the Design of Switchboard Indicating Meters" in this issue of the JOURNAL, will be of very material assistance in solving this problem of selection of apparatus.

A very noticeable improvement in the modern first-class meter, especially from the operator's viewpoint, is the absence of unnecessarily large lettering and intricate scroll work whose ornamental features are questionable, and large trade marks whose presence served only to distract attention from the scale and pointer. Another improvement, which was much needed, is the use of heavy black lines and large, clear-cut figures for the dials.

All of the more prominent electric power companies and many of the stations of moderate size now have meter departments in charge of skilled managers, fully equipped for calibrating and repairing all instruments in use on the system. They can determine for themselves, by competitive tests, which meters best suit their conditions. This fact has been of considerable assistance to meter designers, and has resulted in a development not possible from purely laboratory tests. The old school of design depended upon laboratory research, without giving sufficient attention to actual service conditions. Evidently a commercial meter produced in this way would be at a disadvantage as compared with one produced in line with actual experience in heavy service.

It is interesting to note the activity which has been shown by the Bureau of Standards in the systematic development of elaborate equipment and facilities for the calibration of various types of

meters. The Bureau has issued a considerable number of valuable publications pertaining to this and allied subjects. A recent pamphlet, "Reprint No. 163", gives reliable and interesting data regarding comparisons of many types of American direct-current switchboard voltmeters and ammeters. C. H. Sanderson

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Investigation of Double Voltages

The article in this issue by Messrs. Dwight and Baker should prove of great interest to the operating man, since it describes in detail and analyzes lucidly a phenomenon which he is liable to encounter at any time. The extreme difficulty of dealing with the electrical properties of circuits containing iron is well known. At any given instant the inductance of such a circuit is a function of the current flowing at that instant and, therefore, the ordinary equation of the inductive circuit does not hold. Messrs. Dwight and Baker have shown that it is possible to obtain an approximate graphic solution for the final or steady conditions in a circuit consisting of capacity in series with a variable inductance. In carrying out the calculations the equivalent sine waves of e.m.f. and current are used and the results agree fairly well with the test values. As an actual fact the wave forms are considerably distorted, especially when the iron approaches saturation. This is particularly true during the initial period of starting, before stable conditions are reached. At each point of this period, conditions are such that the sum of the counter-e.m.f.'s is equal to the impressed e.m.f. For any induction in the iron a solution can be obtained for this condition. Added to this solution will be the solution for the current values in such a circuit when the impressed e.m.f. is considered equal to zero. This latter condition is similar to that arising when a string, which has been stretched between two supports, is caused to vibrate. The initial amplitude of the vibration is dependent on the force applied. After the application of the force, the string still vibrates, yet the sum of the forces internal involved is equal to zero; that is, there is now no externally applied force. If an intermittent force is applied to such a string the resultant vibration at any instant will be equal to the combined effects of the applied force and the inherent forces due to the previous applications. The initial impulse in the electric circuit is that due to the initial application of an e.m.f. Different results will occur if this application takes place at different points of the e.m.f. wave. The

oscillations set up by the initial impulse will be superimposed on the wave of normal frequency produced by the steady application of the e.m.f., but will die out as time passes until a steady value is reached. These values are, of course, modified by the fact that a change in induction of the transformers also changes the inductance of the circuit and thus changes the natural frequency of the oscillations. For any given effective value of the exciting current there may be an infinite number of solutions which will satisfy these conditions, each solution, of course, giving a different wave form for the exciting current. For example, there may be harmonics in the wave form of the exciting current which have the effect of making its maximum value higher than that of the equivalent sine wave, and yet the effective value of the counter-e.m.f. in the transformer for this value of the exciting current may be less than that of the equivalent sine wave. These harmonics in the current wave may cause the e.m.f. across the condenser to be peaked in such a way that the harmonics in this e.m.f. wave will be equal and opposite to those in the transformer e.m.f. wave, thus giving a resultant counter-e.m.f. of simple sine wave form.

It is to be regretted that an oscillograph was not used in carrying out these tests, so that a better physical idea could be formed of the transient phenomena taking place in such circuits. For instance, it would have been very instructive and of great interest to have had a record of what passes on in the circuit during the interval in which the current changes from an initial value just above that which occurs in the unstable position denoted on the curve of counter-e.m.f.'s to the steady value corresponding to the larger current value, after the transient oscillations have died out. During this period the inductance of the circuit passes from a value in which the inductive reactance is greater than the capacity reactance to one in which the inductive reactance is less than the capacity reactance. The inductance at a certain point and interval has, therefore, a value which in a magnetic circuit containing no iron would produce resonance.

It is to be hoped that the practical instructions given in the article for obtaining this phenomenon without endangering apparatus will stimulate others to make further investigation of this interesting subject by means of the oscillograph. C. FORTESCUE

Eight Years of the Journal

The present issue completes the eighth volume and the most successful year in the history of the JOURNAL. With the gradual broadening of the editorial policy has come a corresponding increase in the number of readers, and in the variety of interests represented by them. It has been the aim to retain the original method of treatment—of expressing technical facts in concise and simple form—while discussing the large variety of topics which may properly be included under such headings as,—the application and operation of electrical apparatus, prime movers, the central station, power generation and distribution and allied subjects.

Editorial ideals are necessarily unattainable—one must select from the material obtainable at the time, for each issue, and thus the actual magazine as published usually represents only a partial realization of the original conception of the most suitable material for presentation. It is well at the end of the year for subscribers, as well as editors, to glance back through the record for the past twelve months and see in how far the results secured are satisfactory; to determine just where improvements can be made, what parts of the field should be given more attention, and whether the general method of presentation is all that is to be desired. Readers of the JOURNAL can do much towards making it what they wish, by suggesting ideas which they think can to advantage be incorporated in the magazine.

The present volume is the largest yet issued, containing 1 148 pages, an increase of 150 pages over 1910. The volumes for the eight years form a reference library of 6 500 pages. The extent to which these books are used may be judged by the fact that 8 800 volumes, representing over 100 000 single copies, have been supplied by the JOURNAL direct. There is no means of knowing how many additional copies are being preserved by those who have their volumes bound independently.

In the Question Box Department 689 inquiries have been answered to date, covering a great variety of engineering topics. Many subscribers have suggested that they would like to have this material available in book form for ready reference. This is one of the problems which the readers of the JOURNAL can assist in solving. If there is a sufficient demand for them the questions and answers will be classified in accordance with the topical method of indexing and published in book form. It is the desire of the editors that JOURNAL readers express themselves freely in all matters looking towards the improvement of the magazine.

POWER REQUIREMENTS OF A STEEL TUBE MILL

A. G. AHRENS

IN the last few years remarkable progress has been made in the application of electric power to rolling mills, including both the main and auxiliary drives. There are now installed over 175 000 horse-power in large motors driving the main rolls, and over 600 000 horse-power in smaller motors on tables, shears, etc. This progress has been general, and electric drive is now being considered for practically every type of mill. Among these, tube or pipe mills occupy a prominent place. In the tube mills, especially those using the welding process, progress has been very rapid and there are several mills of this kind entirely motor driven, steam finding a place only in the generating station.

One of the first tube mills to adopt electric drive was that of the Spang-Chalfant & Company, of Etna, Pa. At this plant small tubes are made by the "butt welding" and large tubes by the "lap welding" process. Unless otherwise stated, the descriptions and illustrations here given cover the making of 18 inch pipe by the lap welding process, and three-quarters inch pipe by the butt welding process.

The stock from which the pipes are made consists of rolled steel plates of suitable length and width, called "skelp." The travel of the material, through the different processes, from the skelp to the finished pipe, cut off to exact length and threaded, is shown diagramatically in Fig. 1.

The service requirements of motors for this kind of work are exceptionally severe. Many of the motors must operate in close proximity to the furnaces, and hence are subjected to high temperatures. The passage of the metal through the rolls must be continuous, as, if a pipe gets stuck, a considerable delay may result. For this reason no circuit breakers or fuses are provided, and motors are chosen of rugged mechanical structure and large torque, and are expecteed to continue in operation in spite of adverse circumstances. The heating effect of the load in most cases need not be considered, as it is very intermittent in character and as the mills usually are rolling pipe of a smaller size than the maximum for which the motors are selected. On the other hand, the possible high initial temperature of the motors must be considered in determining the allowable temperature rise.

On account of the severe operating conditions, excessive heat and large amount of dust and dirt, induction motors with squirrel cage secondaries are used almost exclusively. Practically all of the motors drive through large gear reductions, and in the majority of cases they run continuously in one direction, the operation and reversing of the rolls being accomplished by means of clutches. Although the load is of a very intermittent character in most instances, the peaks are nearly always of too great duration to allow the satisfactory use of flywheels.

The charging buggy, shown in Fig. 2, illustrates an application of a non-reversing motor to a drive which must be reversed from 100 to 150 times an hour. The frequent reversing of large motors is, of course, objectionable both on account of the strains on the motor and on account of the heavy rushes of current in the

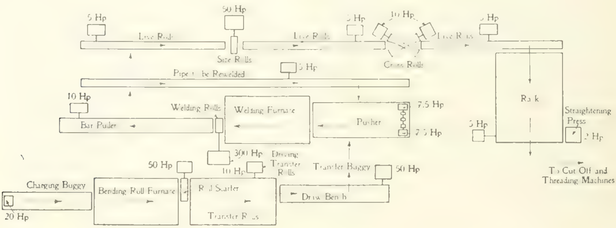


FIG. 1—DIAGRAM OF TYPICAL LAP WELD TUBE MILL

The skelp is placed on the charging table by a crane, and passes through the various processes in the direction indicated by the arrows.

transmission system. In the Spang-Chalfant plant this motor is of the mill type construction, with a squirrel cage rotor, and runs continuously in one direction. It has a double shaft extension, each end being connected through an induction clutch and a set of gears to the drum which drives the cables. Thus for operation of the buggy in the forward direction one clutch is energized, while for reversing, the second clutch is used. On account of the use of induction clutches, with the motor in continuous operation, the load is picked up very gradually without excessive peaks.

The motor on the scarfing rolls, Fig. 3, also operates continuously in one direction, there being no occasion for reversing the rolls. During the time between passes which, as shown by the curves, Fig. 4, averages about four and one-half minutes, the motor operates under a friction load of about 50 percent of full

load. The load period, while a plate is passing through the rolls, lasts about ten seconds. The power required varies with each piece, depending on how near to exact width the skelp is. The power also varies with the size of the skelp, the curve in Fig. 4 being taken while skelp for 18 inch pipe was being scarfed, the capacity of the mill being 24 inch pipe. Although the load on this motor is very intermittent and the peak load occurs for only four percent of the total time, a flywheel cannot be used to advantage as the time required for the skelp to pass through the rolls is too

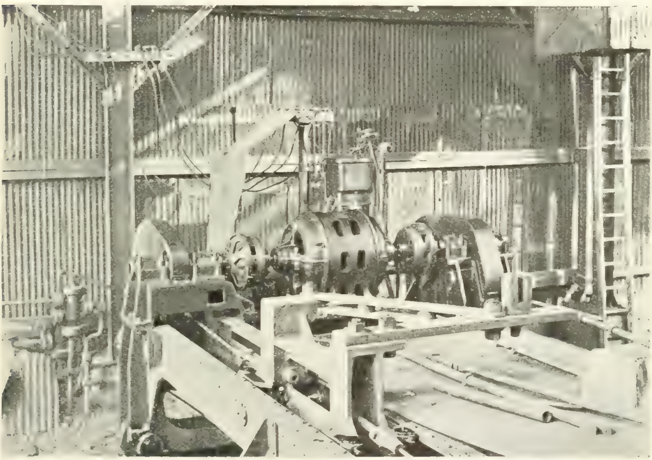


FIG. 2—20 HP, 875 R.P.M. MOTOR DRIVING CHARGING BUGGY OF BENDING ROLL FURNACE

The charging buggy consists of a steel frame work (shown in foreground), mounted on wheels and attached to an endless wire cable. A straight bar is fastened by one end in the holder, and the other end rests on the table, and pushes the skelp into the furnace. A second motor, not shown in the illustration, is used to move the buggy back and forth before the furnace, in order to charge the entire bed of the furnace.

long. The motor must therefore be depended upon to pull the piece through the rolls under all conditions. Reference to Fig. 3 shows that this motor must operate in very close proximity to the furnace, and to the heated skelp.

It is possible, especially for pipes of small or medium size, to scarf the skelp in special motor-operated scarfing shears, although

this method is not common. In this case also the load is very intermittent in character, the power load occupying about 45 percent

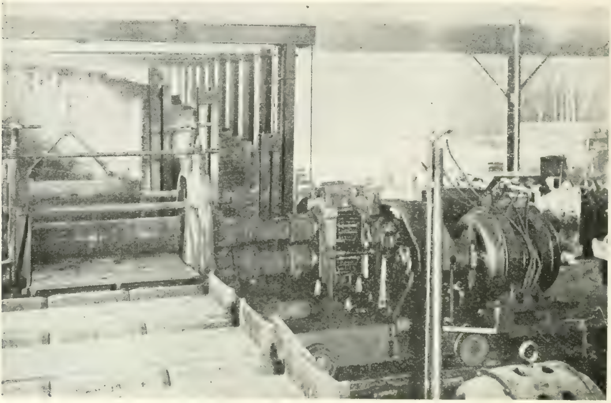


FIG. 3—50 HORSEPOWER 575 R.P.M. MOTOR DRIVING SCARFING ROLLS

The motor is geared to the rolls through a flexible coupling, the whole being mounted on a common bed plate which runs on rails so that the rolls can be located in any desired position before the furnace doors.

of the total time of operation. The actual amount of power at the peaks depends entirely on the amount of metal removed, and is independent of the size of pipe being made.

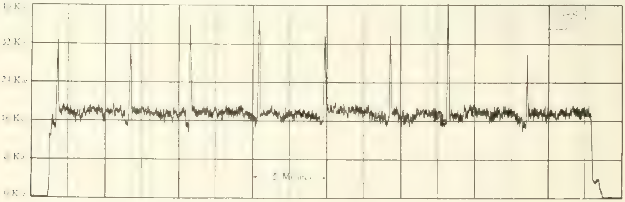


FIG. 4—GRAPHIC METER RECORD OF MOTOR DRIVING SCARFING ROLLS

Speed of rolling 180 ft. per minute. It should be noted in connection with this and the succeeding graphic meter charts that their purpose is to show the nature of the load rather than actual values, which in almost every case vary over a wide range. In no case is the material manipulated equal in size to the rated capacity of the apparatus. All charts are read from right to left.

After leaving the scarfing rolls, the skelp is carried forward on the transfer rolls, shown in the left foreground, Fig. 3, to the

draw bench. Here it is attached to an endless chain by means of mechanical tongs or jaws and is pulled through the bender on the draw bench, where it is formed in a die around a mandrel into circular shape, with the edges overlapping but not closed. The motor and the chain operate continuously, the friction load being equal to about 15 percent of full load. About eight seconds are required for the bending operation. The pipe is then rolled down an incline to the transfer buggy in front of the welding furnace.

The transfer buggy is a motor operated truck, carrying a trough to receive the pipes from the draw bench, and hold them

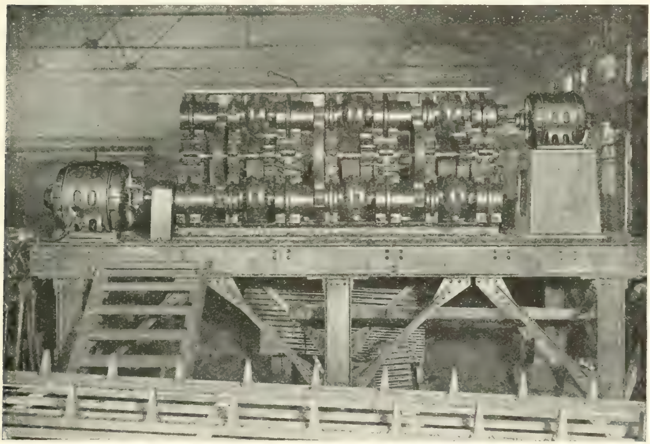


FIG. 5—7.5 HP, 850 R.P.M. MOTORS DRIVING WELDING FURNACE PUSHER

while the truck is moved back and forth in front of the welding furnace, under the welding furnace pushers. It is driven by a five horse-power direct-current mill type motor, which is equipped with a solenoid operated stop brake in series with the motor. The buggy is in continual operation, it being estimated that the brake is set over one thousand times per hour.

The pushers feeding the pipe into the welding furnace present an application essentially similar to the charging buggy in that induction clutches are used to allow a non-reversing motor to be used for service which requires frequent reversing. The applica-

tion has been worked out to greater detail, however, as shown in Fig. 5. The pusher consists of three endless cables, revolving on drums. From each cable is suspended a frame work, having a holder, in which one end of a steel bar is placed, the other end engaging the pipe while it is still in the transfer buggy. The drums which drive the cables are mounted on a shaft which is in turn geared to two shafts revolving in opposite directions, each driven by a motor. By means of the clutches any drum can be driven in any direction, only one drum being operated at a time.

FIG. 6—LAP WELD FURNACE—BENT PLATE READY TO CHARGE

Showing the method of charging the furnace at the McKeesport works of the National Tube Company. As may be noted, the pusher is mounted directly on the charging buggy and is operated by a motor-driven drum and cable.

The pipe which is still at a red heat from the bending operation, is brought to a welding temperature in a furnace of the Siemens regenerative type. It is then pushed from the furnace in a suitable position to enter the welding rolls, being directed by troughs in the floor of the furnace.

A view of the welding rolls from the end opposite the furnace, is shown in Fig. 7. A 300 horse-power, 450 r.p.m. motor is geared to the rolls, with a large flywheel connected to the main

gear, as shown in Fig. 8. By mounting the flywheel in this manner, it operates at a much higher speed than if connected directly to the rolls and a much smaller wheel can be used to produce the same flywheel effect. The distance between the bending and welding furnaces is very small in this plant, making it impossible to mount the flywheel between the gears and the motor.

The pipe is in the rolls about three seconds during which time the load on the motor is increased, as shown in Fig. 9, to six times the friction load. At the time the curve was taken about

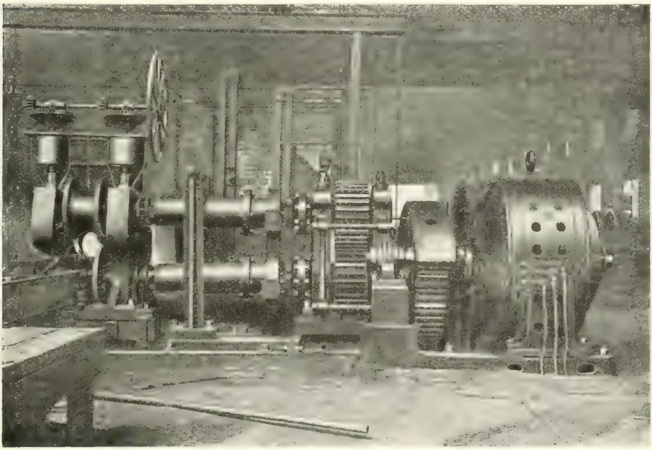


FIG. 7—300 HP, 450 R.P.M. MOTOR DRIVING WELDING ROLLS

The pipes are so placed in the furnace that when they emerge and pass into the rolls the lap is on top. A cast-iron ball or header, of the same diameter as the inside of the pipe, is attached to the end of a steel bar, several feet longer than the pipe, and is placed centrally between the rolls. This ball forms a mandrel to secure the correct inside diameter of the pipe during the welding, and serves to reduce the thickness of the metal at the weld to the same as the rest of the pipe.

18 pipes were being welded per hour or one in three and one-half minutes. The peak load is on the motor about 1/70 of the cycle. It will be seen therefore, that this duty is of the most intermittent kind, and that the motor must be selected for its ability to stand the momentary overload rather than for its continuous capacity.

From the standpoint of production also, the momentary overload capacity of the motor is given important consideration. If a pipe sticks and becomes cold, valuable time is lost in releasing it from the mill and this must be avoided if at all possible. There are no protective devices in the circuits, and a motor is installed large enough to pull the pipe through under practically any conditions. This fact accounts for the comparatively low average load shown by some of the curves. It should be noted also that the welding roll motor, as well as several others, is situated very near the furnace, which makes it necessary to give the capacity of the motor special consideration; the temperature of the surrounding air being over 100 degrees F. even in winter.

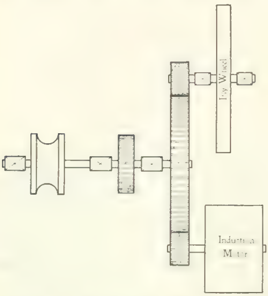


FIG. 8—PLAN OF MOTOR AND FLYWHEEL ON WELDING ROLLS

Speed of rolls, 89 r.p.m. Flywheel, 375 r.p.m. Diameter of flywheel, 6 ft., weight, 3 000 lbs.

The bar puller, shown in Fig. 10, consists of small revolving rolls, which grip the bar and pull it one way or the other, the reversing being done by a mechanical clutch. The load produced is very irregular, as shown by the curve in Fig. 11. The peaks occur when the bar is being run to the rolls, and again when the bar is returned.

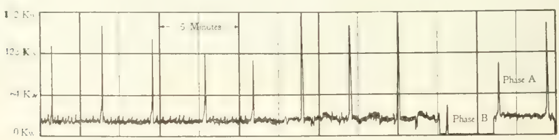


FIG. 9—GRAPHIC METER RECORD OF MOTOR ON WELDING ROLLS

The prolonged peaks are due to the power required to bring the flywheel back to speed. At the beginning of this curve, Phase A and then Phase B were recorded separately to determine the power-factor. As this type of meter is non-reversible, power-factors below 50 cannot be determined. The fact that Phase A by itself records slightly greater values than both together on no load, indicates that the power-factor was a little less than 50 percent on no load. The power-factor at the peaks was about 75 percent.

The pipe is lifted from the racks in front of the welding furnace by a set of hydraulically operated levers, shown at the ex-

treme right in Fig. 10. If inspection shows that the weld is perfect, the pipe is rolled down an incline to the live rolls feeding

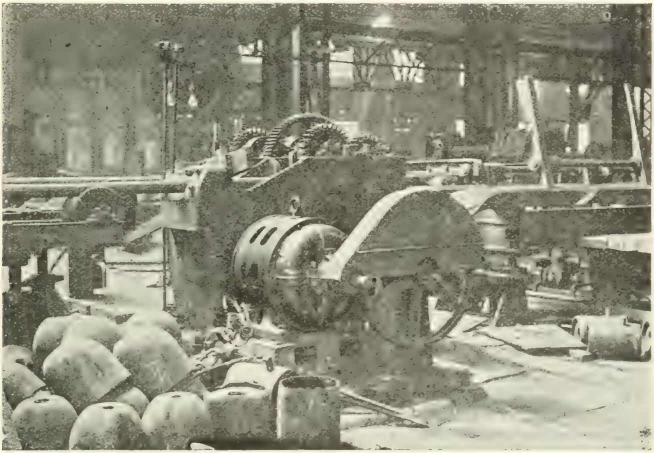


FIG. 10—10 HP, 850 R.P.M. MOTOR DRIVING BAR PULLER

After the full length of the pipe has been welded, the ball is knocked off the bar and the latter is withdrawn by the rolls on the bar puller. Several of the balls, which are cleaned from scale and used repeatedly, are shown in the foreground. The incandescent lamps are used as signals to indicate the proper time for opening the furnace doors to allow a new pipe to be pushed into the welding rolls.

the size rolls. If the weld is not perfect, the pipe is raised on an hydraulically operated turn-table, and turned end for end be-

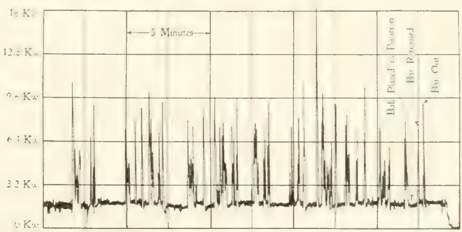


FIG. 11—GRAPHIC RECORD OF MOTOR DRIVING BAR PULLER

fore returning to the welding furnace. This gives a back lap which produces a more perfect weld than would be possible with two rollings in the same direction.

After welding, the pipe, still white hot, is run through the size rolls, which reduce it to correct external size, and then through the cross rolls where, with a whirling motion, it is straightened. It is conveyed to the size rolls by the live rolls, Fig. 12. To insure accurate sizing, the pipes are usually passed through the rolls three times, the reversing of the rolls being accomplished by means of a clutch. This operation also requires the reversing of the live rolls, which is done by reversing the motors, thus producing a very peaked load on the motors. As

FIG. 5—10 HP. 590 R.P.M. MOTOR DRIVING LIVE ROLLS
Sizing rolls in background.

shown in Fig. 14, the load on the sizing rolls is similar to that at the welding rolls, though the peaks are not so severe. Due to the greater duration of the peaks, a flywheel would be of no assistance in smoothing out the load curve. For this application a motor with a large starting torque and liberal over-load capacity is required. The cross rolls are driven through a double reduction gear by a separate motor for each roll. To insure simultaneous operation, both motors are controlled from the same switch, no starting box being necessary.

A number of very interesting features may be brought out by an analysis of the power curve for these motors, shown in Fig. 16. It will be noticed that the power on the motor drops off

FIG. 13—50 HP, 590 R.P.M. MOTOR DRIVING SIZING ROLLS

for an instant as the pipes enter the rolls, and then rises to the full load value. This is probably due to the fact that the velocity of the pipes along the live rolls is greater than their linear velocity through the cross rolls. Thus the pressure on the gears is temporarily relieved, until the motor catches up in speed. The succeeding peaks are caused by the inertia of the pipe as the rotary motion is started, and by reversing the motors while the pipe is in the rolls, which occurs twice with each pipe. During the time that this curve was taken, one of the pipes got

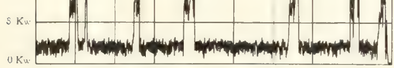


FIG. 14—GRAPHIC RECORD OF MOTOR DRIVING SIZING ROLLS, SIZING 18 INCH PIPE

The heavy peaks are caused by the reversal of the rolls under load by means of friction clutches. Speed of roll, 46 r.p.m. Tubes passed through the rolls three times.

stuck in the rolls. This is a condition which is liable to occur at any time, and which the motor must be able to handle. In this

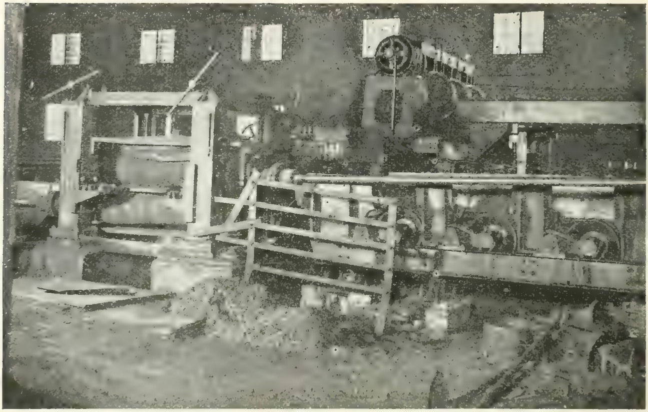


FIG. 15—CROSS ROLLS DRIVEN BY 10 HP, 850 R.P.M. MOTORS

The surface of the rolls forms a hyperboloid of revolution, and they are set at such an angle that the straight line portion of the curve is tangent to the pipe throughout the length of the roll. The pipe is given a combined twisting and forward motion, tending both to straighten the pipe, and to reduce it to exact size. The rolls shown in the illustration are set for four inch pipe. The motor is connected through reducing gears to the shaft at the right.

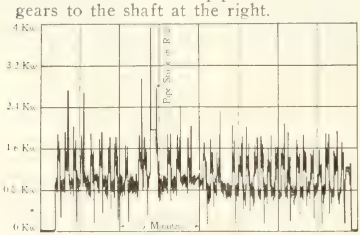


FIG. 16—GRAPHIC RECORD OF MOTOR DRIVING UPPER ROLL OF THE CROSS ROLLS

Speed of rolls, 84 r.p.m. The straight horizontal line in the record indicates that the control circuit of the meter was broken, as the moving element in the type of meter used is actuated by a small motor.

particular case, the sticking was not caused by any fault in the pipe, but occurred because the power was thrown off temporarily. When the power came on the lines again, the motors started up with the pipe in the rolls, requiring very heavy starting current. The power was well within the capacity of the motor, however, in this particular case as the pipe was only four inches in diameter, while the capacity of the rolls is eight inch pipe.

After the pipe has passed through the cross rolls, it has the correct inside and outside diameter, and is approximately straight. It is then run out on the racks and allowed to cool. Before being

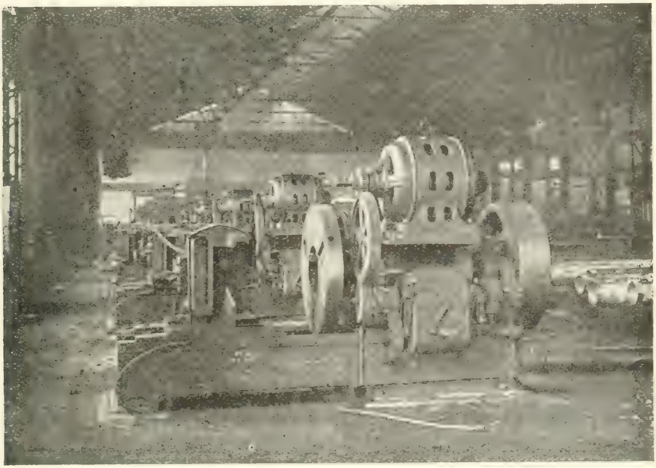


FIG. 17—10 HP. 500 R.P.M. MOTORS DRIVING PIPE THREADERS AND CUTTING OFF MACHINES

cut off to standard length and threaded, the pipe is passed through a straightening machine of the press type, with a flywheel mounted on the cam shaft. Two cylindrical dies, about twelve inches in

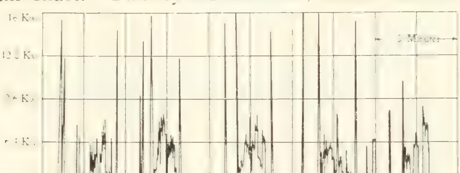


FIG. 18—GRAPHIC RECORD OF MOTOR DRIVING PIPE CUTTING OFF MACHINE

length and of the same diameter as the pipe, are pressed firmly around the pipe every six to twelve inches of its length, removing all inequalities.

The pipe cutting off and threading machine represents a final

application which requires the most rugged characteristics on the part of the motor. The record shown by the curve in Fig. 18 was taken while cutting 18 inch tubes at an average cutting speed of 38 feet per minute. The average load on the motor while cutting is shown by the curve to be about six kw. The starting conditions are exceptionally severe, however, as the motor is started simply by closing a switch. The motor was reversed for the reaming operation while running, causing a very heavy peak, and

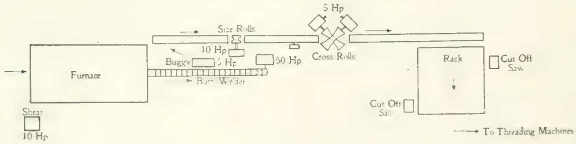


FIG. 19—DIAGRAM OF TYPICAL BUTT-WELD TUBE MILL

Live rolls driven by two horse-power motors are provided between the cross rolls to avoid handling the pipe. The pipe is started into the side rolls by a man with tongs and is picked up from the trough beyond the cross rolls by a rack which is driven by a five horse-power motor. The cut off saws, driven by ten horse-power motors remove the ragged ends while the pipe is still hot.

was again reversed to set the machine for the next pipe. This manipulation is, of course, very severe on the motor windings, and on the gearing.

BUTT WELDING

All pipe over three inches in diameter is made by the lap welding process as described. With smaller pipe it is possible to combine several of the operations into one by butt welding the joints. The diagram of a butt weld mill, Fig. 19, shows the

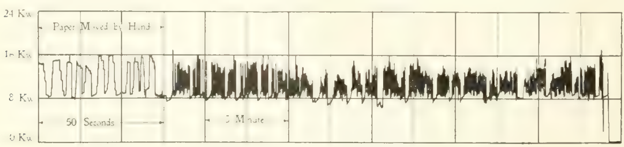


FIG. 20—GRAPHIC RECORD OF MOTOR ON BUTT-WELDER

At the time this curve was taken, 600 three-quarter inch pipes were being welded per hour, or ten per minute.

greater simplicity of this arrangement. The front corners of the skelp are cut off with the shears before it is placed in the furnace, to assist in starting it through the mandrel. In place of being heated twice, the skelp in the butt welding process is brought at once to a welding temperature, and the bending and welding are accomplished in one operation. The forward end is grasped by a tong grip which is attached to a traveling chain and is drawn

through the bell very much as in the lap weld bending process. The difference consists in the fact that the mandrel is so shaped that the edges of the skelp are forced together under considerable pressure causing them to weld. No ball is used, as with small sizes of pipe it is unnecessary.

The power requirements for a motor for butt welding are very similar to those for the draw bench in the lap weld bending process, in that the motor operates continuously in one direction. No flywheel is used because, as shown in the power curve, Fig. 20, the interval between peaks is hardly sufficient at times to allow a flywheel to regain its speed. For this reason, and also because of the fact that a delay caused by lack of sufficient power to pull the pipe through the bell is liable to become very costly, the motor must be selected of ample overload capacity, and with very large starting torque.

After welding, the pipes are run through sizing and cross rolls, and cut off to size and threaded the same as the lap welded pipes.

SUMMARY

Owing to the large capital investments and high labor costs it is absolutely essential in the manufacture of steel products that work proceed with the greatest possible continuity. No interruptions are tolerated that can possibly be avoided. The service is very severe, and in the majority of cases is continuous 24 hours per day. However, electric motors have demonstrated their ability to meet these conditions. In the case of the above plant, the motors have been operating almost continuously since their installation, over three years ago. Owing to their rugged and liberal design they have required practically no repairs and no attention, except a regular inspection of bearings, oil, etc. In fact, for two lap weld mills only three men are required to attend the motors, one being the chief electrician, another his assistant, who is a mechanic, and the third an oiler. These men also attend to the cranes and make any necessary changes in wiring, etc.

One advantage in electric drive, which should not be overlooked, is that by means of graphic meters, installed on the motor circuits, a permanent graphic record can be obtained of the different operations accomplished by the motor driven machines. In this way, data respecting amount of power, cost of work, efficiency of machines and operators can be obtained as by no other method and changes and improvements made accordingly.

OPERATING CHARACTERISTICS OF COMMUTATING-POLE MACHINES

J. M. HIPPLE

DIRECT-CURRENT commutating-pole motors and generators are coming into such general use that a clear understanding of the characteristics of this type of machine is desirable. The users of direct-current machines generally, are evidencing a desire to be fully informed regarding the performance of these machines and it is believed that a discussion of certain characteristics will be of interest. The theory on which the commutating-pole motor is based has been discussed at length and often and therefore will be covered very briefly here.

Motors—The practice of shifting the brushes in non-commutating pole motors to secure the best commutating conditions is due to the fact that such a shift brings the brushes into a position where the short-circuited coil (which is the coil in which the current is being commutated) is within the influence of the field from the pole tips. The movement of the coil in this field generates a voltage which tends to neutralize the voltage of self-induction and reverse the current so that, at the instant the coil passes from under the brush, there will be no sparking.

A brush position can usually be found in a shunt non-commutating pole motor where good commutation can be effected. It must be remembered, however, that when this is done, commutation is largely dependent on the field from the tip of the main pole. This field does not have such an intensity as to be an ideal means for producing perfect commutation. To produce ideal commutation, this field should, under varying load, vary in strength directly in proportion to the current in the armature, since the voltage of self-induction in the armature varies in this proportion. On the contrary, however, in a shunt wound motor the field is somewhat weakened as the load comes on, due to the reaction of the armature field on the main field. Again, in the case of a motor operating at less than its normal voltage, or at an increased speed through weakening of its field, the commutating field is weakened and sparkless commutation made more difficult to obtain. The same holds true in the case of a generator or exciter operating at less than its rated voltage.

The function of the commutating-pole is to provide a field for commutation which will, under all conditions of load and voltage, have such a strength as to produce complete reversal of the current in the short-circuited coil and, therefore, sparkless commutation. The action is the same as in the non-commutating pole motor with the brushes shifted; the difference being in the means employed to produce the commutating field and in the results secured. By employing a separate pole located midway between the main poles, several distinct advantages are gained.

1—The commutating field is so located that the correct brush position is the same for either direction of rotation.

2—A series winding may be used, thereby generating a field that is directly proportional to the current in the armature. This field is substantially unchanged when the motor is operated at less than rated voltage, or at increased speed by weakening the field.

3—This field is not weakened by armature reaction as the load comes on, because a sufficient number of turns are used to neutralize completely the counteracting effect of the armature at the commutating point between the main poles, with additional turns to produce the necessary commutating field. It is, therefore, not necessary to change the position of the brushes with different loads to get the best commutating conditions.

4—Summed up, the great advantage of the commutating-pole is in being able to properly locate and proportion a field for comutation. By suitable proportions of poles and windings, this field may be produced of such shape and strength that good commutation may be secured under the following conditions, all of which present difficulties in the design of non-commutating pole machines:—

a—Continuous operation at increased speed by field control.

b—Continuous operation at voltages considerably less than normal.

c—Continuous operation under widely varying loads.

d—Operation at overloads for considerable periods.

NUMBER OF COMMUTATING POLES

The number of commutating poles used is a matter of design and construction. The theory and action is the same whether the number of commutating poles used is the same as the number of main poles or half that number. The use of the smaller number of poles would not be permissible in a ring wound armature

but practically all armatures of commercial motors are drum wound.

In a drum wound armature it can readily be seen that, by providing a commutating field in alternate interpolar spaces, one side of each coil undergoing commutation will be in the influence of the field. It is then necessary only to make the strength of the field of proper value to generate the voltage in the coil necessary for good commutation. Reference to Fig. 1 may be of use in making this clear. This figure shows a four-pole wave, or two-circuit wound armature. For sake of clearness, only four of the coils undergoing commutation are shown, and they are shown side by side instead of top and bottom as they are usually arranged in the slot. The main poles are *E F G H*, the interpolar spaces being designated *A B C D*. If there is a commutating pole in each interpolar space, it is clear that both sides of each short-circuited coil will be in the commutating field. If the commutating poles are located only at *A* and *C*, reference to the diagram will make it equally clear that one side of each short-circuited coil will be in the commutating field. Since the two sides of the coil are in series, a greater voltage generated in one side of the coil serves the same purpose as a smaller voltage generated in each side. It must not be inferred from this that it is permissible to remove half the commutating poles and coils from a machine without a change in the proportions of the commutating poles and the number of turns of their coils. If the commutating poles are sufficiently liberal in cross-section, no change in them might be necessary, but in every case the number of turns per coil would have to be increased. The amount of this increase varies, but averages around 30 percent.

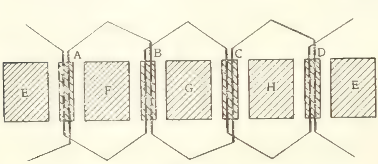


FIG. 1

COMMUTATING POLE COIL CONNECTIONS

The commutating winding is connected in series with the armature, and it should always be borne in mind that whenever the current is reversed in the armature, it should be reversed in the commutating winding. A frequent error in the use of commutating-pole motors in reversing service is to consider the com-

mutating-pole winding as the same as the series winding in the main poles of a compound-wound machine, and reverse the motor by reversing the motor leads at the brush holders. This should not be done as it reverses the current in the armature only and produces destructive sparking when the motor is running in one direction of rotation.

SPEED REGULATION OF MOTORS

Commutating-pole motors, as a rule, have better inherent speed regulation with varying load than non-commutating pole motors. If the effective field in a motor remained absolutely constant as the load came on, the speed would drop, being proportional at all loads to the difference between the applied voltage and the IR (resistance) drop, or in other words, proportional to the counter-e.m.f. In almost every motor, the effective field is varied to some extent as the load comes on. In a commutating-pole motor, there are several possible causes for weakening of the effective main field as load comes on. One of these is the effect of demagnetizing ampere-turns due to current in the armature coils which are short-circuited by the brush. These ampere-turns are directly opposed to the main field ampere-turns if the machine is over-compensated and they may be of considerable magnitude. Saturation of the yoke by the interpole flux and demagnetization due to the cross-magnetizing effect of the armature ampere-turns may also be of sufficient magnitude to produce an effect. However, this weakening of the main field as the load comes on causes the motor to hold up its speed. Incorrect brush position has the same effect as in non-commutating pole machines, backward lead in a motor weakens and forward lead strengthens the field.

Instability of Speed—Instability, hunting, surging or racing as it is variously called, is sometimes noticeable in commutating-pole motors though it is not inherent in them as a class. Instability is primarily a result of a rising speed curve, i.e., one showing increase of speed with increased load. If the weakening of the main field described in the last paragraph extends far enough, the speed will rise as the load comes on. This is, of course, true of motors either with or without commutating poles.

A second essential element producing instability is inertia. If there were no inertia in the moving parts, armature or driven load, the instability would not occur even with the rising speed curve. Considering the case of a motor with a rising speed curve driv-

ing a load having inertia; a position of stability may be found under certain conditions when there is a fixed load. As soon, however, as the load is increased, there will be a drop in counter-e.m.f. due to the increased current. At the same time, the effective field will be weakened by the increasing load and, to maintain the counter-e.m.f. corresponding to that load, the speed should increase at once, in the same proportion that the field decreases. Due to inertia, however, the speed does not respond instantly, with the result that the counter-e.m.f. drops further and thus causes the motor to take more current, which in turn further weakens the field and thereby causes the current to increase still further. The amount of energy being drawn from the line is now considerably in excess of that required to drive the external load and it is therefore expended in accelerating the revolving parts, with the result that eventually a point is reached where the counter-e.m.f. of the armature again increases. The current then falls rapidly and the speed more slowly, the action being just the reverse of what took place as the current was rising. The revolving parts now deliver their stored energy to the driven load, the result being that the current falls below what is actually required to drive the load. As soon as the stored energy plus the input to the motor is less than that required to drive the load, the current again starts to rise and the former cycle is repeated. In practice, the time required for this cycle is small and the speed will race up and down as rapidly as the inertia of the revolving parts will permit. In the case of high speed machines or machines having very unstable characteristics, the speed is liable to increase to a dangerous point before reaching the turning point in the cycle.

Means for Preventing Instability—The means most commonly employed for insuring absolute stability of speed is a series or so-called compensating winding. This is a series winding on the main poles which compensates wholly or in part for field weakening due to any of the causes mentioned above. The strength of the effective field is maintained at such a value that the speed will fall off slightly with load, thereby insuring against any instability under any operating condition.

REGULATION CHARACTERISTICS AND PARALLEL OPERATION OF GENERATORS

It is generally understood that the setting of the brushes on direct-current generators and motors has an important bearing on

their operation. It is also commonly known that, when properly designed, commutating-pole machines are ordinarily to be operated with the brushes set in neutral position. The following notes, revised from an engineering instruction book, may aid to an understanding of the regulation characteristics of direct-current machines in general and the proper brush setting for various conditions of operation, such as paralleling of generators, etc., and will serve to indicate some of the advantages of commutating-pole machines.

It is true of direct-current machines in general that the inherent armature regulation characteristics have much to do with the question of their successful parallel operation. When the armatures of two direct-current generators, for example, are coupled in parallel and delivering power to the same external circuit it is necessary, in order to obtain stable conditions, for each armature to tend to "shirk" its load; that is, each must naturally tend to transfer load to the other machine. This tendency to shirk may be either in bad speed regulation due to the prime mover which drives the generator armature, or in the drooping voltage characteristics of the armature itself. A drooping speed characteristic indirectly produces a drooping voltage characteristic in the armature; therefore, both causes lead to the one characteristic, viz., drooping voltage, as the condition for stable parallel operation. This drooping voltage characteristic must be an inherent condition. In practice, the voltage at the armature terminals frequently rises with increase in load, but its rise is due to some condition external to the armature, such as increased field strength, and not to conditions in the armature itself.

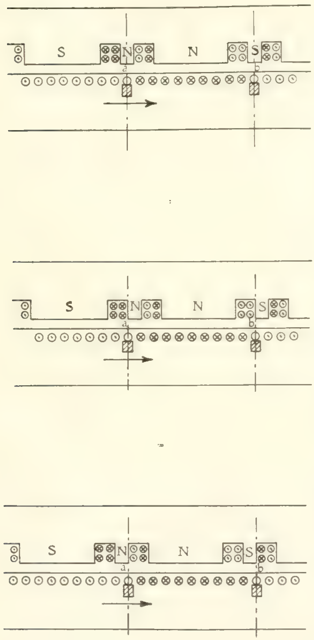
Drooping Voltage Characteristics—Direct-current generators, as hitherto ordinarily constructed, naturally give drooping voltage characteristics in the armature windings. If two such armatures are paralleled they tend to divide the load in a fairly satisfactory manner, provided their prime movers regulate similarly in speed. If means are applied for giving a rising voltage characteristic to the machines, such as series coils in the field, then the armature terminals must be paralleled directly in order to maintain stability. If, for instance, the armatures are not paralleled directly but the paralleling is done outside the series coils, then the operation will be unstable unless the machines still have drooping voltage characteristics. If they have rising characteristics, then parallel opera-

tion is impracticable. If either machine should take an excess of load its voltage would rise, while, that of the other machine would fall due to decreased load. This condition would naturally force the first machine to take still more load and the second one to take still less, until the first machine actually fed current back through the other machine and it would be necessary to open the circuit between them to avoid injury. However, by paralleling the two armatures inside the series coils, that is, between the series coils and the armature terminals, this unstable condition is avoided for two reasons; first, the inherent drooping voltage characteristics of the armatures; and, second, the fact that the series coils are paralleled at both terminals, forcing them to take proportional currents at all times and thus compounding both machines equally.

Rising Voltage Characteristics—If direct-current generators are so designed or operated as to give rising instead of drooping armature characteristics then parallel operation is liable to be unstable. This condition could be obtained in ordinary machines by prime movers which tend to speed up with increasing load, thus producing rising voltage on the armature. Ordinarily, such speeding up of the prime mover would have to be rather large to overcome the normal drooping characteristic of the ordinary armature, However, prime movers of this character are comparatively rare.

Commutating Poles—A second condition which can give a rising voltage is not infrequently found in commutating pole type direct-current generators. As in the case of commutating pole motors the commutating windings are connected directly in series with the armature, but so that their effect will be directly in opposition to that of the winding in the armature. The maximum magnetizing effect of the armature winding is found at the points on the armature corresponding to the coils which are being commutated. The commutating pole is intended to be placed directly over these points and the commutating pole winding normally has such a value that it not only neutralizes the magnetizing effect of the armature winding at these points, but it also sets up a small magnetic field in the opposite direction which assists in the commutation of the armature coil. Therefore, the commutating pole winding must have a number of ampere-turns equal to the maximum ampere-turns in the armature winding, plus the excess ampere-turns necessary to produce the required commutating field strength.

Effects of Different Positions of Commutating Pole—When the commutating pole winding is placed directly over the commutating position of the armature winding, it should have practically no effect on the armature characteristics. This assumes that the commutating field strength is so proportioned as to be exactly correct. However, as mentioned under "Speed Regulation of Motors", in case the machine is over-compensated there will be some effect on the armature characteristics due to the short-circuited currents generated in the coil undergoing commutation. This effect, however, will be neglected in the present discussion.



FIGS. 2, 3 AND 4

Shifting of Brushes—If the commutating pole winding is not placed over the position of the armature winding it will have an effect on the voltage characteristics of the machine tending to either raise or lower the voltage, depending upon the position of the commutating pole with respect to the commutating position. The commutating points on the armature depend directly upon the brush position. If the brushes are rocked backward or forward from the point corresponding to the mid position between the poles, then the position of the commutated armature coils moves backward or forward with the brushes. As the commutating pole is fixed in position it is evident that its relation to the coils undergoing commutation can be changed by the different brush settings. Herein lies a possible trouble in parallel running, for the commutating points can be so shifted with respect to the commutating pole that the armature voltage characteristics can be made to rise instead of droop. As explained before, this is an unstable condition for parallel operation.

Brushes in Mid Position—This may be illustrated by reference to Fig. 2, which represents two main poles and commutating poles, with the brushes set in a position corresponding to the middle point of the commutating pole; the polarity of the respective poles is indicated. The polarity of any commutating pole, when the machine is running as a generator, is always the same as the polarity of the main pole immediately in front of it, as shown in Figs. 2, 3 and 4. When the brush is placed in a position corresponding to an exact intermediate point in the commutating pole it is evident that the armature coils lying between two commutating points, that is, the windings between *a* and *b* in Fig. 2, are acted upon by induction from the main pole and by half the induction from the commutating poles adjacent to the main pole. However, as these two commutating poles are of opposite polarity and the induction is the same from each, it is evident that they have equal and opposite effects on the armature winding between *a* and *b* and therefore do not affect its voltage.

Back Lead—In Fig. 3 the brushes are given a slight back lead so that the commutation is under the trailing magnetic flux from the commutating pole. It is now evident that between *a* and *b* the induction is from the main pole and from one commutating pole principally. With the back lead at the brushes, this commutating pole is the one immediately back of the main pole and therefore of the same polarity. This commutating pole therefore becomes a magnetizing pole and adds to the e.m.f. generated between *a* and *b*. As the strength of this commutating pole is zero at no load and rises with load, it is evident that it tends to give an increased voltage between *a* and *b* as the load increases and thus tends to produce a rising voltage characteristic instead of a drooping one. As stated before, the number of ampere-turns in the commutating pole is considerably greater than in the armature, but ordinarily the effect of these ampere-turns is almost neutralized by the opposing effect of the armature winding. However, with the back lead, as indicated in Fig. 3, the opposing effect of the armature winding is shifted to one side of the commutating pole and thus the commutating pole ampere-turns become more effective in actually magnetizing the armature, but become less effective in creating a commutating field for the coils which are now being reversed by the brushes. On account of this less effective field it may be necessary in practice to increase the ampere-turns on the

commutating pole still further in order to bring the trailing magnetic fringe up to a suitable value for producing proper commutation. It is evident that this increased number of ampere-turns on the commutating pole increases the induction on that part of the commutating pole which is affecting the armature voltage as well as on that part which is producing the commutating field. This further increases the voltage between *a* and *b*.

With a back lead, therefore, the commutating pole may have the same effect as the series winding on the main field; that is, it may compound the machine so that the voltage at the terminals is of rising instead of falling characteristic, even without any true series winding on the main poles. The machine therefore becomes an equivalent of a compound wound machine and if there is no equalizer between the commutating pole winding and the armature terminal, the generator may be unstable when paralleled with others.

Forward Lead—The case where the brushes are given a forward lead is shown in Fig. 4. Comparing this with Fig. 3, by the same reasoning it is evident that the commutating pole is now opposing the effect of the main pole in the winding between *a* and *b*. The commutating pole therefore tends to produce a drooping voltage characteristic and has just the opposite effect to that of the series winding. In this position of the brushes the commutating pole winding tends to give good characteristics for parallel operation, but as the effect of the commutating pole is in opposition to the main pole it is evident that more series winding is required on the main field in order to over-compound the machine as a whole. Also, with the brushes in this position the commutating pole is not as effective in producing good commutation and therefore more ampere-turns are required on the commutating pole winding. Therefore, both the commutating pole winding and the main series winding must be increased when the brushes are given this forward position; but parallel operation should be stable.

Correct Position—It is evident, therefore, from the above considerations, that for best results the brushes should be so set that the true point of commutation comes midway under the commutating pole. If this position is found exactly, then the commutating pole should have practically no effect on the voltage characteristics of the armature, and parallel operation with other generators should be practicable. A very slight forward lead is favorable to paralleling, but lessens the compounding.

As a back lead at the brushes, when the machine is acting as a generator, tends to improve the compounding and lessens the series winding required on the main field, it might be suggested that this gives a cheaper and more efficient machine and that therefore this arrangement should be used, with some means added for overcoming the unstable conditions of paralleling. One means proposed for this latter is an additional equalizer connected between the commutating poles and the armature terminals. This has been used in one or two instances, but in principle the arrangement is inherently wrong. When the commutating pole windings are paralleled, then the currents in them must divide according to their resistances. This condition would not be objectionable provided the armature currents also always varied in the same proportion. With slow changes in load this condition might be obtained. However, there are conditions of operation where the armature currents will not rise and fall in proportion and therefore the commutating pole windings, with this arrangement, would not always have the right value to produce the desired commutating fields. For the proper arrangement each armature should be connected directly in series with its own commutating poles and the currents in the two should rise and fall together for best results. It is evident that this condition will not be obtained when an equalizer is connected between the armatures and commutating poles, and this solution of the probleem should therefore be avoided.

Brush Position on Motors—The action of the commutating pole in affecting the field of a motor when the brushes are given a lead is the same as in a generator, except that with backward lead the commutating and main fields included between *a* and *b* are of different polarity, and with forward lead they are of the same polarity. In view of the tendency toward instability which would result if the brushes were given backward lead and the poorer commutating conditions if given forward lead, shifting of the brushes from the neutral position is very objectionable.

Brush Setting—All the foregoing leads to the fact that very accurate brush setting is required on commutating pole machines and, furthermore, that when such setting is once obtained it should not be capable of ready adjustment or change. For this reason commutating pole machines should not have a brush rocking gear. In machines where such gear is present it would be better, in general, if the brush rocking mechanism were removed after the proper

setting of the brushes is once obtained, and means should be employed for locking the brushes in this correct position.

The correct setting of the brushes is not difficult under the present manufacturing methods, as it is the practice to build the machine so that the correct position of the neutral is known by the time the machine is assembled. This involves manufacturing the armature to exact information regarding the throw of the coil and leads and the location of the commutator bar with reference to the center of the slot. It is the best practice, therefore, for the correct brush setting to be determined by the manufacturer and the brushes definitely located in this position, which, when once found, need not be altered. To locate the correct setting of the brushes in a machine which has not been manufactured with these precautions in mind, the correct mechanical neutral therefore not being known, is rather difficult in many cases. In motors, the practice most frequently followed, is to locate the neutral by checking the speed of the motor in both directions of rotation, when carrying a load. When a brush position is found which gives the same speed in both directions of rotation, it can be assumed that this is approximately the correct position. This method is of course subject to some errors, principally errors in reading the speed and error due to the brush not making contact over its full face in both directions of rotation. In addition to this method, there are two methods frequently employed which may be properly distinguished as the "mechanical" method, and the "electrical" or "kick" method.

Mechanical Method—Where the armature conductors can be traced from the commutator bars back under the poles, it is feasible in general to locate the correct setting by the position of the commutated coil with respect to the commutating poles. In standard practice the throw or span of the coil is made, as nearly as possible, equal to the pole pitch. In a parallel type of winding where the number of slots is an exact multiple of the number of poles, the space of the coil can be made exactly equal to the pole pitch. In this case, if the winding can be traced through, the brushes can be so set that a coil or turn exactly under the middle of the commutating poles has its two ends connected to the two adjacent commutator bars which are symmetrically short-circuited by the brush; that is, the insulating strip between these two bars should be under the middle of the brush. To carry this out properly it is necessary to trace the conductor, with absolute exactness,

through the slots. When there are several separate turns side by side in one slot, it is advisable to select a middle, or approximately middle, turn for determining the brush setting.

In the case of a two-circuit or series winding, it is more difficult to determine the brush setting by tracing out the coils, for the number of slots in such windings is usually not an exact multiple of the number of poles and therefore the span of the coil is not exactly equal to the pole pitch. In this case the position of the coil must be averaged; that is, one edge or half of the coil may be slightly ahead of the middle point of its commutating pole, while the other half is slightly behind the middle of the commutating pole. Even if the position of the coil is properly fixed it is not easy to fix exactly the corresponding brush setting, as the two commutator bars to which the coil is connected do not lie adjacent to each other, as in a parallel type of winding, but are two neutral points apart. Also, the number of commutator bars is not an exact multiple of the number of poles (except in some rare cases where there is an idle bar) and therefore they do not have a symmetrical relation to the brushes. The best that can be done is to average the brush position as well as possible.

If the winding is chorded, that is, if it has a span considerably shorter than the pole pitch, then its position will have to be averaged in the manner described above.

In some cases it is not practicable to trace out the coils in this manner, as the end windings may be so covered that it is not possible to follow an individual coil from the commutator to the slot.

Electrical or "Kick" Method—The electrical neutral for brushes may be correctly and simply located if due care is exercised. With all the brushes raised from the commutator and the machine standing still, if the shunt field be excited to about one-half of its normal strength and the field current suddenly broken, voltages will be induced in the armature conductors by a transformer action. Consideration of these voltages in conjunction with the diagram in Fig. 5 will show that the maximum voltages are produced in those conductors located in the interpolar space (between the main poles) and that the minimum voltages are produced in those conductors located nearest to the centers of the main poles. It will also be found that the induced voltages in conductors located at equal distances to the right and left of the main pole centers are equal in magnitude and opposite in direction.

Hence, if the terminals of a low reading voltmeter (say five volts) be connected to two commutator bars on opposite sides of the center line of a main pole, and exactly half way between the center lines of two main poles, the voltmeter will show no deflection when the field current is broken, because there will be equal fluxes in opposite directions through equal numbers of turns. The spacing of these commutator bars is evidently the correct distance between brushes on adjacent brush arms. In Fig. 5 a ring wound armature is shown for simplicity. The leads come straight out to the commutator bars and the neutral points, in this case, will be midway between the main poles. In actual practice, the armature conductor which lies in the exact neutral zone on the surface of the armature leads to a commutator bar located approximately under the center of a main pole, hence the electrical neutral on the commutator will be found approximately in line with the main pole centers.

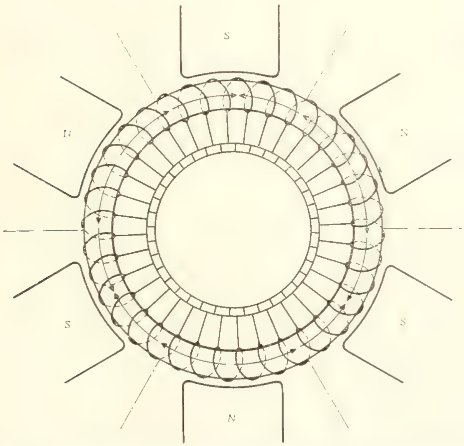


FIG. 5—DIAGRAM OF RING-WOUND ARMATURE, SHOWING ELECTRICAL OR "KICK" METHOD OF DETERMINING NEUTRAL POINT

The arrows indicate voltage induced when field is opened.

To find the electrical neutrals in practice, two pilot brushes are made of wood or fibre to fit the regular brush holders and each brush carries in its center a piece of copper fitted for making line contact with the commutator and for connection to the voltmeter leads. These two brushes are put into regular brush holders located on adjacent brush arms and connected to the terminals of the voltmeter. The holders and brushes are then shifted slightly forward or backward as necessary until breaking the field current

occasions no deflection on the voltmeter. This neutral point is noted and the pilot brushes are then similarly used in another pair of brush holders on adjacent arms and so on, all of the way around the commutator, noting whether each position proves to be at a neutral point. The average of the positions of neutrals thus obtained gives the correct running location for the brushes.

If the armature winding is perfectly symmetrical and the commutator has an integral number of segments per pole (i.e., a number which may be expressed by a whole number), a position can be obtained where there will be no deflection of the voltmeter connected between adjacent neutral points when the field current is broken; but with the two circuit armature windings extensively used in the smaller sizes of machines, it is impossible to have an integral number of commutator segments per pole. In such cases it is necessary to make a number of repeated trials and to so set the brushes that the sum of the voltmeter deflections obtained by taking readings all of the way around the commutator will be a minimum, the positive and negative signs of the readings being disregarded.

If no deflection occurs between brushes spaced from each other by an odd number of poles, an additional check on the electrical neutral is established. For example, in a six pole machine the pilot brushes may be placed in diametrically opposite holders and the neutral found as before described. This method has the advantage that by its use a point of no deflection or zero reading is obtainable where the number of commutator bars is divisible by two, as in many six-pole machines.

Possible Adjustments for Effecting Successful Parallel Operation—When a commutating-pole generator is running alone, or where it is operating properly with other machines and the commutation is satisfactory, it is unnecessary, of course, to look into this question of locating the best brush setting. In those cases, however, where the machine does not parallel properly with others and it is evident that the brush setting is wrong, then if the above procedure cannot be followed, a better brush setting can be found by determining the voltage characteristics of the armature. This can be done by operating the machine with various loads with the series field winding cut out of circuit. If, under this condition, the voltage either rises with increase in load, or droops but very little, then it is evident that a greater forward lead would improve the operation. The brushes could then be shifted slightly

forward and the regulation noted. After a brush setting has been obtained which gives a considerably larger drop in the voltage, then parallel operation should again be tried with this brush setting, the series field coils, of course, being connected in circuit. After proper paralleling is obtained, then it may be necessary to re-adjust the strength of the commutating field. If the machine has had a considerable back-lead before and is shifted to the no-lead condition, then it may be necessary to weaken the commutating pole winding somewhat. If the new brush setting, however, should correspond to as much forward lead as it had back lead before, then the commutating pole strength may not require readjustment and the commutation may be just as good as before. After proper conditions have been obtained the brush holder position should be marked to be readily found, if necessary.

Another feature wherein a commutating pole machine is different from the non-commutating pole type, is in the amount of series winding, as explained in connection with the discussion of brush position. In the non-commutating pole type the brushes are usually given a considerable forward lead. In consequence of this lead a part of the armature ampere-turns are actually effective in demagnetizing the field, and extra series turns are necessary simply to overcome this demagnetizing effect, without accomplishing any useful result.

On the commutating pole type, however, with the brushes set properly there is no lead at the brushes and therefore none of the armature turns are tending to directly oppose the main field. In consequence of this the number of series turns may be reduced and the resistance of the series coils is correspondingly reduced. When operating commutating pole machines in parallel with other types it may be necessary to increase the resistance of the series circuit in order that the commutating pole machine may take its proper share of the current through the series coils. This result is best obtained, in general, by a resistance connected in series with the series coil and not by a shunt connected across the series coils of the other machines. A shunt across a series coil of one machine is, in reality, a shunt across all the machines which are operating in parallel; and it may be more effective in one machine simply because of the resistance of the leads connecting the various machines. These statements apply to other types of machines as well as to those with commutating poles.

NOTES ON THE OPERATION AND MAINTENANCE OF FACTORY LIGHTING SYSTEMS

C. E. CLEWELL

ARTIFICIAL shop lighting may be divided into the three general divisions: 1—The design; 2—The installation; and 3—The operation and maintenance. Interest in this phase of shop equipment will most naturally concern improvements in the design together with better methods of installing the lamps, but no lighting system, however perfectly designed and installed, will retain its efficiency and continue to furnish satisfactory illumination unless maintained with systematic care and attention.

Under operation and maintenance will be included in this article questions relating to the supply circuits; economy in the use of carbons for arc lamps; inspection of tungsten systems; cleaning of reflectors, and maintenance records. These items, while not covering the entire field of the up-keep of lighting systems, will nevertheless serve to indicate some of the problems which are involved, as well as methods of handling them systematically in both the small and the large factory.

IMPORTANCE OF SYSTEMATIC UP-KEEP

To the average shop man the importance of a systematic maintenance of factory lighting systems may not be evident. Such matters as the burning out of carbon filament and tunsten lamps, and the gradual deterioration of glass and metal reflectors and globes, are often not given much concern in the general shop economy. In some cases it may even occur that the lighting system is allowed to deteriorate to a certain state of equilibrium where each man looks after his own lamp and the foreman must send in a complaint when repairs are needed. With more modern lighting systems, however, where the lamps are usually mounted overhead, the method whereby each man is the guardian of his own lamp no longer applies.

Evidence of the importance of a daily inspection and renewal of a system of tungsten lamps, equally applicable in principle to all other illuminants, is presented in Fig. 1, which shows how the renewal of lamps in one large factory jumps to a high value after Saturday and Sunday, these being the only days in the week on which no inspection and practically no renewals are made. Obviously the neglect to inspect and renew promptly all burned out

lamps would soon result in inferior service and much loss of time to the workmen with the consequent annoyance. Fig. 2 shows the result of neglect in the matter of regular cleaning of reflectors which are used with tungsten lamps. These curves were obtained

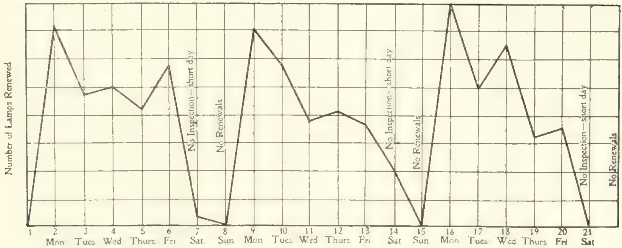


FIG. 1—NUMBER OF LAMPS RENEWED DAILY IN A FACTORY INSTALLATION

Indicating the increase in renewals after two days on which no inspection and practically no renewals are made.

from tests on two typical glass reflectors which had been in service in a factory for nearly four months without being washed. When taken down and tested it was found that about 30 percent of the light produced was lost in the first case and about 40 percent in the second, due to accumulations of dirt on the surface of the glass.

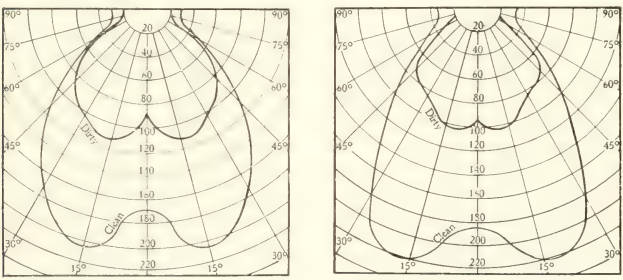


FIG. 2—DISTRIBUTION CURVES OF TWO GLASS REFLECTORS BEFORE AND AFTER BEING WASHED

Losses of light equal to 30 and 40 percent were found in these reflectors because they were allowed to go four months without being washed.

Interpreted into money values the second case represents a loss of about 12 cents for the period, calculated on certain practical assumptions as to energy used throughout this period of four months for each reflector and an energy cost of one cent per kilowatt-hour.

The total cost of taking down, washing and replacing this reflector amounted to three cents, so that the economy, not to speak of the greater satisfaction in the light furnished by a frequent and systematic cleaning of reflectors and globes, is at once apparent.

THE SUPPLY CIRCUITS

The supply circuits for revised or new lighting systems must have an adequate carrying capacity to avoid excessive voltage variations with different loads. The lighting circuits should also be entirely free from any power loads such as shop motors, elevators, ventilating fans, and the like. While new lighting methods with more highly efficient lamps may be looked to for a saving of energy over older methods, this is not always the case. Some old systems

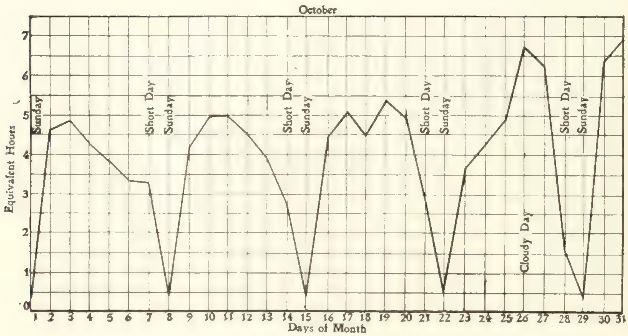


FIG. 3—CURVE SHOWING THE LIGHTING LOAD IN A TYPICAL FACTORY SYSTEM

Indicating the great variation of the load on the supply circuit from time to time.

provided so little light that an equal amount of power is required with improved and more highly efficient lamps in order to insure the requisite increase of light to secure the best results, and in some cases even more energy will be required by the new system than by the old. For these reasons the supply circuits as well as transformer capacity should be given careful consideration when new systems are contemplated as substitutes for old systems, and the best results will be possible only when the circuits are of sufficient size to permit of wide variation in the number of lamps in use with a small variation in voltage. Fig. 3 shows the variation in the extent to which lamps are used from day to day in a large tungsten installation.

ECONOMY IN THE USE OF ARC LAMPS

A first consideration when installing arc lamps in a factory is their accessibility. Arc lamps should never be installed so as to be inaccessible for trimming and general maintenance and this feature should be given weight when laying out the system, as the convenient location of lamps at the outset will obviously go far to promote a low maintenance cost.

One of the problems which confronts the lamp department in large factories is the waste of carbons, resulting from lamps which are trimmed before the carbons are entirely consumed. This is, of course, particularly the case where large numbers of short burning arc lamps are in service. A practical method of checking up and

FIG. 4—HOLDERS AND PANS FOR REDUCING WASTE OF CARBONS

reducing this waste consists in providing a carbon holder for each trimmer. When the trimmer starts on his round one of these holders filled with carbons is taken, and as the lamps are trimmed the short carbons are returned to this holder. On reaching the lamp department, this holder containing only a few unused carbons and the remnants of the used carbons which have been taken from the newly trimmed lamps, is turned into the storeroom. These short pieces of carbon are emptied by the storeroom clerk into pans and are inspected each day by the lamp foreman, who is thus enabled to detect any carelessness on the part of the trimmer. The carbon holders together with the pans on the shelves into which the short carbons are emptied are shown in Fig. 4, each pan being given the check number of the trimmer to whom it belongs.

THE INSPECTION SYSTEM

In a factory where nearly 10 000 tungsten lamps are in service, it has been found necessary to develop a system of inspection and prompt renewal of all burned-out lamps. In this factory all the lamps are inspected once per day except on Saturday, which is a half-holiday, and Sunday. The inspectors, following a definite route, note all burned-out lamps, together with such other items as lamps whose candle-power has deteriorated due to the life limit of the lamp, missing lamps, broken switches, loose or burned-out fuses, and the like.

Considerable judgment must be exercised in the detection of lamps which have deteriorated in candle-power due either to accumulations of dust or to the natural life limit. A tungsten lamp which appears only slightly dusty may have suffered a deterioration of relatively large amount, hence they should not be allowed to get excessively bad before being cleaned or renewed. Similarly, re-

Location	Style of lamp	Out	Blackened	Fuse	Missing	Column
Dept A	100 watt 110 v Cl	2				7-8 west
" B	100 " "	1				9-10 "
" C	100 " "	1				15-16 east
" D	60 " "	1				7-8 "
" E	60 " "			1		5-6 west
" F	250 " "	2				8-9 "
" G	100 " "				1	4-5 east
" H	500 " "	1				8-9 west
" M	60 " "	2				10-11 "
" O	100 " "	1				18-19 east

(a)

Location	Style of lamp	Out	Blackened	Fuse	Missing	Column
Dept A	100 watt 110 v Cl	2				7-8 west
" B	100 " "	1				9-10 "
" C	100 " "	1				15-16 east
" D	60 " "	x O.K.				7-8 "
" E	60 " "			1		5-6 west
" F	250 " "	2				8-9 "
" G	100 " "				1	4-5 east
" H	500 " "	x Fuse				8-9 west
" M	60 " "	2				10-11 "
" O	100 " "	x O.K.				18-19 east

(b)

FIG. 5—TYPICAL INSPECTION REPORT FOR TUNGSTEN LAMPS, IN DUPLICATE

The diagram at the left shows the form as it is made out by the inspector and sent out to the renewal man. At the right is the same form as it is returned with his notations.

flectors suffer a large depreciation of their reflecting efficiency due to dust and dirt even before this can be readily detected by the eye.

Careful attention, therefore, should be given to the reporting of those locations where it appears that reflectors are in need of washing, even if there is some question in the mind of the inspector, at least until such time as a regular chart or schedule of cleaning is in force. It should always be remembered in work of this kind that one lamp burned out, or one very soiled reflector, may affect the work of a man whose loss in time due to the poor light may be worth many times the cost of a new lamp, or the washing of a reflector.

The inspectors start on their rounds early in the day and upon their return to the office a report is made up like that shown in typical form in Fig. 5 (a), this report being sent to the lamp de-

partment as early in the day as possible, usually about 11 A.M. The locations of the lamps to be renewed are indicated by the department concerned and by the numbers of the columns between which the lamps are located. Upon the receipt of this report by the lamp department, a clerk turns over the lamps required for renewals to the renewal men, after marking the department and column numbers on the lamp boxes. In this way the lighting installations are kept in good shape from day to day. It is obviously important to facilitate this renewal work by a clearly understood marking of the exact location in which burned-out lamps are to be found. To this end it has been found helpful to number all columns throughout the factory.

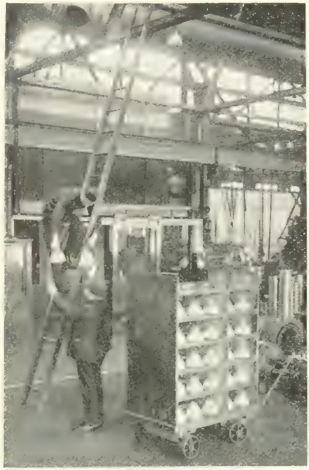


FIG. 6—TRUCK FOR HANDLING REFLECTORS AND METHOD USED IN REPLACING SOILED WITH CLEAN REFLECTORS FROM A LADDER

FIG. 7—METHOD OF USING HAND RACKS FOR CARRYING REFLECTORS TO AND FROM SMALL INSTALLATIONS

This inspection report is very useful as an indication of the maintenance costs from month to month. For this purpose the report shown in Fig. 5 (a) is sent to the lamp department in duplicate. After the renewals have been completed the duplicate shown in Fig. 5 (b) is returned to the recording office with all corrections marked thereon, showing lamps which, although reported

as burned out, were found O. K., perhaps on account of being loose in the socket, or on account of a defective fuse. This corrected duplicate is then made the basis of a monthly maintenance record, as far as the number of renewed lamps is concerned.

Another feature of this system is the inspection of lamps left burning when not needed. This is helpful now and then during the noon hour and after the factory is closed as a check on the care which is being exercised in turning out lamps when not required. If lamps are found burning in a section when no one is at work, a note is sent to the head of the section, calling attention to the matter.

CLEANING OF REFLECTORS

In addition to the foregoing items relating to the inspection

FIG. 8—VIEW SHOWING METHOD OF CLEANING REFLECTORS

system, the inspection men, as previously stated, report the reflectors in need of washing, as a check on a regular schedule which is based on the rate of deterioration of the reflectors due to dust and dirt in the various locations, as found by observation and test.

The problem of handling and washing thousands of glass reflectors at frequent intervals is somewhat involved when the installations, as in the case before referred to, number nearly 500 separate and distinct systems, covering an extensive floor space. The two methds proposed for taking care of this item were:— First, to remove all soiled reflectors to a central point for washing; and second, to provide washing stations at various points through-

out the factory and thus to localize the washing for certain portions of the factory.

In this particular factory it was found best to centralize the washing, removing all reflectors to one point for cleaning, on account of the complication of providing facilities at a number of points for an operation which would be intermittent. When an installation is in need of washing, a truck, loaded with about 100 clean reflectors, is hauled to the location in question, where the soiled reflectors are taken down and clean ones put in place immediately. When the men leave such a location with the soiled reflectors, the installation is in good shape. Such a truck and the method of exchanging a soiled for a clean reflector is shown in Fig. 6. In some instances the renewal work must be done from the top of a crane, in which case the lamps and reflectors are passed out from a mezzanine floor, or are drawn up in a basket.

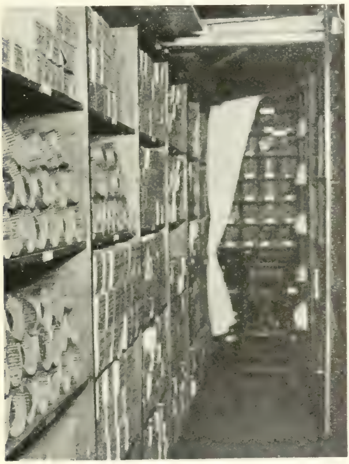


FIG. 9—STORAGE ROOM FOR LAMPS OF VARIOUS SIZES

When the installation is small, a truck is not always required, and in such case hand racks, such as shown in Fig. 7, have been found useful. The reflectors are placed over a vertical rod, one over the other, after which the handle is inserted at the upper end of the rod.

The soiled reflectors after being loaded on the truck or on the hand racks, are removed to the central supply rooms where they are washed with hot water and soap, as indicated in Fig. 8, which shows that the soiled reflectors are placed on the right hand drain board, the washing is done in the trough at the center with scrubbing brush, soap and hot water, and the clean reflectors after being rinsed in clean hot water are placed on the left hand drain board ready to be dried with a cloth. After being dried, the reflectors

are wrapped in tissue paper prior to being stored on shelves ready for further use.

Other methods have been given trial, such as dipping the soiled reflectors in diluted acid for cutting the dirt, washing without drying by means of a cloth, and the like, but the method as just described has been found most satisfactory. The dust deposited on the surface of glass or metal reflectors clings to the surface persistently, and a scrubbing brush with soap and hot water seems to be the only feasible method for the operation. Reflectors cleaned by this method present a luster almost equal to that when new.

FIG. 10—VIEW SHOWING METHOD OF STORING REFLECTORS AND GLOBES OF VARIOUS SIZES AND TYPES

RECORDS AND STORAGE

In large plants, records of renewals and renewal parts are essential so as to avoid running out of certain necessary items connected with the up-keep. Figs. 9 and 10 show methods of storing the lamps and reflectors for tungsten systems so as to keep sizes and types separate.

TABLE I—TUNGSTEN LAMP CHART

Location	No. of Lamps	Lamps			Reflectors			Holder	Mounting Height	Ceiling Height
		Size	Volts	Type	Size	Class	Type			

When renewing lamps where a great variety of sizes and types are used, the necessity for accurate charts showing the type of lamp

TABLE II—TUNGSTEN LAMP MAINTENANCE RECORD FORM

Month	No. Lamps Installed	Kw-hrs. per Mo.	Total Lamps Burned Out	Total Lamps Blackened	Total Lamps Missing	Total Renewals—All Sizes	Material Costs		Labor Costs			Total Maintenance Cost per Kw-hr.	Maintenance per No. per unit area for satisfactory intensity	Maintenance Cost per 100 watt Lamp per Mo.
							Lamp Renewals	Broken Reflectors	Renewal of Lamps and Reflectors	Reflector Washing	Indirect Charges			

and reflector in each location is evident. A typical form of chart for tungsten lamps is shown in Table I which provides a con-

TABLE III—ARC LAMP MAINTENANCE RECORD FORM

Month	No. of Lamps	Kw-hr. per Month	No. of Carbons	No. of Globes	Material Costs			Labor Costs				Total Maintenance Cost	Maintenance Cost per Kw-hr.	Maintenance Cost per Lamp per Mo.
					Carbons	Globes	Other Renewals	Globe Washing	Lamp Repairs	Lamp Trimming	Indirect Charges			

venient reference when requests for renewals are received by the lamp department between inspection intervals, or when there is

any uncertainty as to the type or size of lamp in a given location.

The lamp department can also furnish information which is very useful in calculating total maintenance costs in the matter of labor and material used for the various lamps. This information can then be conveniently embodied in a record sheet, a typical form of which is shown in Tables II and III for tungsten lamps and for arc lamps respectively. Information of this kind enables the management of a factory to determine from month to month the expense for lighting, and likewise to compare their own with similar costs of other concerns.

CONCLUSIONS

The three most important items to consider in a new lighting system are:—

1—The cost of the lamps and wiring.

2—The quantity and quality of light.

3—The operation and maintenance cost.

From what has been stated it will be seen that systematic operation and maintenance bear a direct relation to the economy of the lighting systems extending throughout the service of the installation. These expenses are, therefore, most important and should be carefully weighed when considering the first cost of a system. Items two and three are very important, in fact, unusually so in that they refer to the day-by-day operation of the system, and for this reason it may sometimes occur that the most expensive system to install may, by virtue of low operation and maintenance cost, be the cheapest in the long run. It can also be seen that systematic attention to a lighting system is imperative, if the service is to result in satisfaction. A little calculation will often result in the conclusion that the outlay for this phase of factory maintenance as a whole will be more than compensated for by the resulting improvements in service.

MODERN TENDENCIES IN THE DESIGN OF SWITCHBOARD INDICATING METERS

PAUL MacGAHAN

THE increasing size of power plants and the concentration of generating and controlling equipment into small spaces, as often required in large cities, give rise to new problems with regard to the equipment of switchboards. The larger amounts of power to be measured, the greater cost of switchboards, and especially the necessity of convenience in operation, ease of reading the instruments and ability to keep in touch with all parts of the board at once, demand much greater refinement of design than was considered necessary a few years ago. Before selecting types of meters for a given application, their characteristics should be examined closely to see whether they are the best possible under the conditions which are to be met.

COMPACTNESS

A compact arrangement of the controlling apparatus on large switchboards is considered an important element of modern design, due to the following causes:—

A—Cost of space, particularly in large cities.
B—Reduced attendance required to manipulate.
C—Location in operating galleries.
D—Reduced cost of marble, bus-bars, etc.
E—Visibility of all instruments from point of operation.

These features are in many cases of predominating importance, so much so in fact that it is not unusual to find that they have dictated the design of the meters. Thus the meters in some cases have been made to suffer in consequence by a reduction in scale length, or by a change in form to a rectangular type with curved glass, arranged to take as little space as possible.

It is the writer's intention to show that an equal reduction in area occupied by meters can be made through proper design without in the least reducing the scale length, and without having recourse to the troublesome features attending the use of curved scales as in edgewise meters. The principal types of switchboard indicating meters are given in Table I, the area occupied on the marble or the circumscribing rectangle being tabulated, together with the scale length. Space in a horizontal direction is in general more valuable than vertical space; but to compare the above instruments in this

respect is not altogether fair unless a complete layout is made of a proposed switchboard showing the groupings. The writer finds that vertical edgewise meters will group themselves no more satisfactorily than the horizontal, but are somewhat more desirable due to their greater scale length. This latter advantage is, however, offset by the better mechanical arrangement of the movement possible in the horizontal type compared to the vertical. Illuminated dial types have not been shown in the above tabulation due to the fact that their use is generally prohibited where compactness or cost are considerations.

The seven inch "round pattern" instruments have not been considered very seriously for this class of service heretofore on account of the fact that complete lines including wattmeters, power-factor meters, etc., have not been available and on account of their very

TABLE I—COMPARISON OF SCALE LENGTHS AND SURFACE COVERED

TYPE OF METER	AREA MARBLE	SCALE LENGTH
Round Pattern 7½ In. Diameter	58 Sq. In.	5 In. to 14½ In. according to make
Round Pattern 9⅝ In. Diameter†	110 " "	6½ In. to 14½ In. " " "
Horizontal Edgewise 6½ In. x 8 In.	52 " "	6 In.
Vertical " 3 In. x 18 In.*	54 " "	12 In.
Vertical " 4 In. x 18 In.	72 " "	12 In.
Vertical " 5¼ In. x 15½ In.	82 " "	12 In.

†Front connected, space including that taken by terminals.

*Ammeters and voltmeters, only, obtainable in this narrow size.

short scales. These disadvantages have recently been completely overcome in such a way as to place this type of meter on an entirely new basis. In fact, a complete line of seven inch round pattern meters is now available with scales as long as in any of the nine inch types previously made and, therefore, longer than those in any edgewise types available. As shown in the Table I, the space taken up on the panel, i.e., a square enclosing the circle, is practically no greater than in the edgewise forms. Considering their freedom from objectionable curved dials, and ease of reading, this long scale, round pattern, seven inch type appears to be the proper solution of the problem of size.

READABILITY

Under this heading should be considered:—Scale length, scale distribution, form of scale, reflections from glass, and illumination. In a just comparison of scale length it should be borne in mind that if the longer scale is in a larger case, the distance from the opera-

tor must be increased, thus in many instances, losing the advantage. A basis for comparison would be the ratio,

$$\frac{\text{Area marble in square inches of circumscribing rectangle}}{\text{Scale length in inches}}$$

In this respect the principal types vary as shown in Table II.

Concerning scale distribution it is conceded that a uniformly spaced scale is the best. But such scales are only possible in direct-

TABLE II—COMPARISON OF AREA OF PANEL REQUIRED PER SQUARE INCH OF SCALE

TYPE OF METER	Sq In. Area of Panel Required per Inch Length of Scale
7⅝ In. Round Pattern (average)	11
7⅝ In. " " latest	3.9
9⅝ In. " " (best)	7.5
9⅝ In. " " (average)	15
6½ In. x 8 In. Horiz. Edge.	8.7
4 In. x 18 In. Vert. "	6
5¼ In. x 15½ In. " "	6.8
Illum. Dial (average)	16

current D'Arsonval meters and in alternating-current wattmeters. All other alternating-current meters have scale divisions of varying lengths in different parts. In the case of ammeters the importance of accuracy increases with the load and thus proportionately increasing scale divisions are not a disadvantage. If they increase according to a definite law, such as when they are proportional to the square of the current, they are more desirable than if the divi-

TABLE III—COMPARISON OF VOLTMETER POINTER DEFLECTIONS

RATING	SIZE	TYPE	POINT	INCHES PER VOLT
150 V	7⅝ In.	Round Pattern (best) A. C.	115 V	0.16
" "	7⅝ In.	" " (average) A. C.	" "	0.035
" "	9⅝ In.	" " (best) A. C.	" "	0.16
" "	9⅝ In.	" " (average) A. C.	" "	0.05
" "	9⅝ In.	" " (best) D. C.	" "	0.052
" "	6½ In. x 8 In.	Horizontal Edgewise A. C.	" "	0.023
" "	4 In. x 18 In.	Vertical Edgewise A. C.	" "	0.13

sions are artifically made narrow at the upper part. For voltmeters, a comparison of pointer deflection at "normal" voltage, per volt variation is useful. Such a comparison for the various types of instruments is given in Table III.

In alternating-current ammeters and voltmeters, the torque is proportional to the square of the current passing through the coils, resulting naturally in a scale whose divisions increase according to

this relation. There have been many attempts to modify this so as to obtain an approximately uniform scale distribution. Obviously there are two methods to be considered:— First, increase the torque at low loads only and second, reduce the torque at high loads only. Inasmuch as any increase in light load torque would naturally result in increased torque throughout the scale, unless corrective measures were applied as per the second method stated above, the latter is the only one to be considered. This method in general consists in causing the moving element to move into a

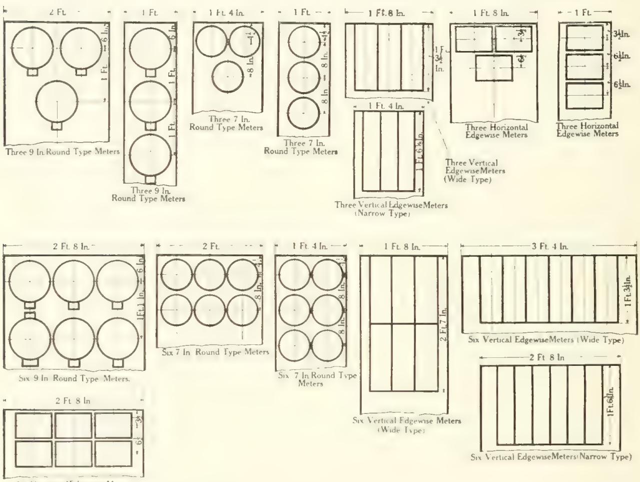


DIAGRAM SHOWING COMPARATIVE AREAS REQUIRED BY VARIOUS TYPES OF METERS ON SWITCHBOARD PANELS

weaker field, as when, in an electro-dynamometer meter, a moving coil is allowed to move so as to become more nearly parallel to the stationary coil; or when, in a moving iron meter, the moving iron is allowed to move out of the field of the stationary iron, or more nearly parallel to the lines of force of the magnet coil. In a disk type induction meter the same effect is produced by reducing the diameter of the disk at the higher load points. In each case, the full-load torque determines the strength of the spring to be used. Any such corrective measure is evidently at the expense of a weaker spring and thus causes greater proportionate friction and lower accuracy throughout.

Due to the above considerations the writer is of the opinion that we can do no better in design than to let the scale distribution follow the natural law of the instrument's torque without applying corrective measures.

An item of increasing importance as affecting readability is that of a proper illumination of the scale and the pointer. The modern tendencies are to limit the so-called "Illuminated Dial" meters having a glass scale illuminated by a lamp from the rear, to switchboards of a highly decorative character, and heavy capacity direct-current panels whose size is determined by the other apparatus mounted upon it. Moreover, the rear illumination is not of much value in a switchboard room whose general illumination has been worked out upon proper lines. Full glass front plates, instead of metal covers with slots in them for the scales, greatly improve the readability by improving the illumination of the dial, and by allowing the whole length of the pointer to be seen, instead of showing only an "index." This has been recognized long ago in European practice, nearly all European meters being of the round pattern, glass front type.

By proper attention to the position of the illuminating source, troublesome reflections from flat glass fronts of meters can be entirely eliminated, a matter of much greater difficulty in the case of the curved glass used in edgewise meters.

APERIODICITY

In the case of direct-current instruments, "critical damping" is the best; that is, an amount of damping that will bring the pointer to rest in the least time. In an alternating-current instrument which may be placed on circuits on which there is a rhythmic interchange of current or of power, it is an advantage to have the movements super-damped, that is, make the damping so strong as to considerably increase the time required for the pointer to reach the true reading. With super-damping a sudden application of full-load will not cause the pointer to swing past the true reading, or collide with the stops. Very light weight movements, due to their quick natural period, are particularly susceptible to this pumping action when on alternating-current circuits, whereas heavier movements which are super-damped tend to integrate the flunctuations, giving a reading of average value.

Owing to the comparatively long and heavy pointers in edgewise meters, the damping cannot be made as satisfactory as in round

pattern meters. Another advantage which super-damping gives to alternating-current meters is the protection afforded during short-circuits. The movement is slowed up sufficiently to greatly reduce the shock. It should be remembered that in ammeters whose torque is proportional to the square of the current, the effect of sudden overloads is much more serious than in D'Arsonval meters whose torque only increases with the first power of the current.

RUGGEDNESS—SIMPLICITY—ACCESSIBILITY

It is important to distinguish between the qualities which make for that great refinement of accuracy necessary in laboratory instruments and the quality of ruggedness which is surely of greater importance when considering meters for switchboard service. Thus for switchboard service it is evidently more desirable to have instruments which will stay correct within say two percent, and on which an initial accuracy greater than one percent is not obtainable, than to install meters designed upon laboratory lines whose initial accuracy can be made much higher but which will not retain an accuracy within two percent after severe service. It is to a large extent true that from a design point of view, high accuracy and ruggedness are antagnoistic elements between which it is the problem of the designer to properly compromise. Movements should be only as light in weight as is consistent with strength to withstand severe service, but should not be heavy enough to damage the jewels. As proved by watthour meter practice the jewels will not suffer appreciable deterioration with a 12 gram moving element, especially if the weight is supported on two jewels, the shaft being horizontal. Thus there is very little to be gained so far as the bearings are concerned by further reducing the weight at the expense of strength. Lighter movements are exceedingly difficult to handle or repair.

Simplicity is a feature closely allied to ruggedness. In order to obtain a very simple moving element, much can be sacrificed if necessary, in the simplicity or cost of the stationary element.

Accessibility of all parts is of great importance from an operating point of view. It is an advantage to be able to get at the whole mechanism without removal from the switchboard. If the "moving element" complete with its bearings can be removed as a unit without disturbing other parts, such as permanent magnets, etc., it will be found to be a great advantage in making repairs or re-adjustment.

A construction that is less rugged than any other, and therefore perhaps least desirable for switchboard work is the moving coil electro-dynamometer type, with flexible connections of great delicacy. These instruments are as a class deficient in torque, their sole advantage being high initial accuracy of calibration.

ACCURACY

Modern generating equipments comprising large units, generally turbine driven, have resulted in a re-adjustment of the comparative importance of the different kinds of electrical errors to which indicating meters are subject. Thus the frequency of a modern plant does not usually vary more than one cycle from normal and therefore frequency errors in meters are less important, whereas formerly this was one of the great sources of error. On the other hand, due to the handling of larger currents and higher potentials, the external magnetic field and also electrostatic effects are greatly increased. The tendency has rightly, therefore, been toward designs which are not greatly influenced by external fields instead of to those not influenced by frequency errors. This probably explains why certain large companies in this country and abroad have preferred the induction type design to all others, as a basis for their manufacture of alternating-current switchboard instruments, as it is well known that these instruments are especially free from external field influences. Nor are they as deficient as is often assumed when it comes to a frequency error. Induction type ammeters and voltmeters having an error of less than one-twentieth of one percent per cycle are now obtainable; thus the error due to this cause in a modern plant would not be noticeable.

Moving iron and moving coil instruments although practically free from frequency errors are extremely subject to external magnetic field effects, and the best practice is to insert heavy shields of laminated iron within the cases to overcome this effect. Without such shields, the sheet iron cases quickly get saturated by an external magnetic field of relatively small strength after which their further shielding effect ceases. Their light torque also causes them to be very susceptible to external electrostatic effects, which generally manifest themselves by attracting the pointers toward the glass or case, thus causing errors. It should be noted that moving coil meters have an advantage over moving iron types in being influenced only by external fields of the same frequency; whereas moving iron meters are affected by both alternating-current and direct-current stray fields.

Permanent magnet instruments when in soft iron cases have but a slight error due to external fields, but if subjected to the excessive fields which are often present when short-circuits occur, may lose a portion of the permanent magnet strength and thus suffer a permanent change in calibration. This can only be guarded against by keeping the meters away from the bus-bars, a good rule being that the meters should not be nearer in inches to any bus-bar than one-fifth of the square root of the maximum load current in the bus-bar.

Temperature errors in instruments are important. The variations in the temperature at the switchboard may be normally + or — 15 degrees C. which would produce considerable error in an instrument not properly designed. A temperature error of one-half of one percent for 15 degrees C. variation should be satisfactory. Alternating-current instruments of either induction, moving coil or moving iron types and direct-current voltmeters of the D'Arsonval type are readily obtainable whose temperature errors are within these limits. The temperature errors in shunted type direct-current ammeters are generally conceded to be somewhat more, the error being accepted so as to avoid the alternative of heavy losses due to high resistance shunts.

Self heating errors, due to change in resistance caused by the heat liberated in the meters themselves, although not so important on meters which are left continuously in the circuit and thus soon reach their working temperature, should nevertheless be avoided.

Ratio, Torque Divided by Weight—The mechanical sources of errors in switchboard instruments are probably of greater importance than purely electrical errors, as the causes which lead to them also reduce the useful life of the instrument, and greatly increases the errors with usage and time. Those instruments that have the highest ratio of torque over weight of movement will have the greatest accuracy and longest life, if equivalent in other respects. In the writer's opinion the minimum satisfactory value for this ratio, in a switchboard indicating meter is 0.15 when torque is expressed in centimeter-grams, and weight, in grams. This value can of course be made much lower for laboratory types of instruments.

PRINCIPLES OF OPERATION

It is conceded universally, that for direct-current ammeters and voltmeters the D'Arsonval, permanent magnet construction is the best. When such meters are designed with movements which can

readily be removed without first disturbing the magnetic circuit by removal of the pole pieces, they cannot be excelled for this class of service.

For alternating-current service, the three principles of operation found in the best instruments are as follows:

Moving Iron Electro-Magnetic Type—Good initial accuracy of calibration. Approximate freedom from frequency and temperature errors. Ratio of torque to weight—low. Some makes too delicate. Easy to repair. Subject to both alternating-current and direct-current external fields unless heavily shielded. Short scale length.

Moving Coil Electro-Dynamometer Type—Highest in initial accuracy of calibration and freedom from errors due to frequency and temperature. Ratio of torque to weight—low. Delicate. Difficult to repair. Subject to external fields of same frequency unless heavily shielded by internal laminated iron shields. Short scale length.

Induction Type—Good initial and continued accuracy. Ratio of torque to weight—very high. Rugged and simple movements. Easy to repair. Extremely long scales and high readability. Frequency errors greater than in moving coil or moving iron types. External field errors only due to fields of same frequency, in certain directions, and are slight.

In choosing instruments for alternating-current switchboard service due consideration should be given to the relative advantages of the three types as outlined above. It is often advisable for the purchaser to make competitive examinations and tests of the best meters of the various types before deciding which to use. In judging the results of such tests too much stress must not be laid upon *initial accuracy*, as the effect of the qualities which conspire to reduce the accuracy and life in actual service are most important as a basis for the best comparisons. Nor must high finish be confused with the quality of good workmanship. This last consideration is one of which it is very difficult for any one not an expert in meter practice to judge, except through the actual results obtained in service.

DOUBLE VOLTAGES IN CIRCUITS HAVING CAPACITY AND INDUCTANCE

H. B. DWIGHT and C. W. BAKER

THE experience of observing a new electrical phenomenon was recently accorded those present in a generating station while a 2 400 volt generator was being tested for grounds by the rather common expedient of placing a voltage transformer and voltmeter between one generator terminal and ground. The operator read 3 600 volts, which he knew to be a "phantom ground". He was much surprised on repeating the test on the same terminal to obtain only 1 400 volts, and on making a number of repetitions, he obtained sometimes one reading, and sometimes the other. In the present article these erratic voltages, for lack of a better name, are called "double voltages".

That double voltages are a serious source of danger, and not a mere theoretical curiosity, is plainly shown by the experience at the above mentioned generating station, for after the peculiar voltages had been observed several times, the generator broke down to ground. After being repaired and connected to the line, the test for grounds was again made. The double voltages were observed once more, and immediately another generator which was in parallel with the first, became grounded. The insulation of all the machines was now found to be in a weakened condition and in the next fortnight practically all the generators in this large hydraulic power plant broke down, and much expense and hardship was caused in three cities which were thereby deprived of their power supply for extended periods of time.

It is important to understand the cause of this dangerous phenomenon and how to avoid its occurrence, as the conditions giving rise to it are liable to occur in almost any electric power station. It has been observed in connection with many different generators, from those of the largest size down to machines of only 100 kilowatts.

The connections for an ordinary test for grounds on an alternating-current generator are indicated in Fig. 1. The generator is run at no load and normal voltage, and the charging current due to the capacity (condenser effect) of the generator windings flows through the voltmeter and registers a "phantom ground." If a

voltage transformer and voltmeter are used, as in Fig. 2, the phantom ground will still be observed, unless the transformer is too large.* The conditions are, in effect, as shown in the simple circuit of Fig. 3.

When the transformer is of a certain size compared with the generator, double voltages may be registered by the voltmeter. Both values of voltage are consistent with the properties of the circuit, and may be calculated when the electrostatic capacity of the generator windings to ground, and the magnetizing current and iron loss current of the transformer at various voltages, are known. It is impossible to tell which of the two voltages will be registered, as this depends on the part of the generator voltage wave at which the circuit is closed.

The cause of the phenomenon will be evident from a brief analysis of the fundamental conditions involved. In any electrical circuit the current flowing is such that the vector sum of the

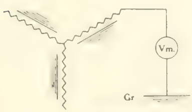


Fig. 1

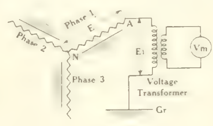


Fig. 2

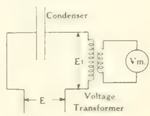


Fig. 3

counter-e.m.f's. set up by it in the respective parts of the circuit is equal to the e.m.f. impressed. It is well known that when current flows in an inductance and a non-inductive resistance in series, the voltage across the resistance is in phase with the current, while the voltage across the inductance is out of phase with the current, and hence the two voltages are out of phase. Then the numerical sum of the two voltages as measured individually will exceed the total as measured by a voltmeter across the two elements. Likewise, when a condenser and a resistance are in series, the numerical sum is greater than the actual resultant. It is also greater when an inductance and a capacity are in series. As the counter-e.m.f's. of inductance and capacity, (each assumed to be without resistance) are exactly opposite in phase, the resultant counter-e.m.f. of the circuit is the numerical difference of the counter-e.m.f's. of the two parts.

The vector diagrams for a circuit consisting of inductance

*This effect was discussed by Mr. S. M. Kintner in the JOURNAL for March, 1906, p. 176.

and capacity in series are given in Fig. 4 (a) and (b), in which E represents the voltage impressed on the circuit, E_1, the counter-e.m.f. across the inductance, and SI_0, the counter-e.m.f. across the capacity. The current I_0 is in quadrature with both E_1 and SI_0. At (a) is shown the case where the inductive reactance is greater than the capacity reactance, and at (b) the case where it is less. If E_1 is now considered to be the counter-e.m.f. of an inductance which has a small amount of resistance, the diagrams are as in Fig. 4 (c) and (d). The current I_0 is no longer in exact quadrature with the voltage E_1 but is slightly nearer in phase with it, as true energy is now being expended, while SI_0 is in exact quadrature with I_0, and so has advanced in phase in relation to E_1.

A voltage transformer produces the same counter-e.m.f. in a circuit as an inductance in series with a comparatively small

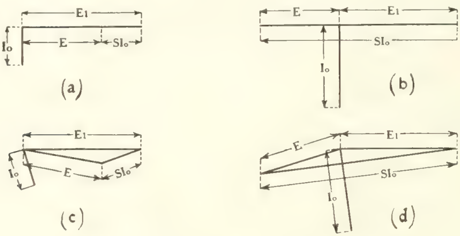


FIG. 4

amount of resistance. A voltage transformer in series with a condenser is shown in Fig. 3, and the vector diagrams for this circuit are given in Fig. 5 (a), (b) and (c), which are seen at once to be the same as Fig. 4 (c) and (d). The current I_0 is partly in phase with the voltage E_1, as it must expend true energy in supplying iron loss and voltmeter loss. The two cases, which in Fig. 4 represented a large and a small inductive reactance, are also shown in Fig. 5. The phenomenon of double voltages depends on the fact that both these cases can be produced by the same transformer, first, when the iron core is magnetically unsaturated, and second, when it is saturated. Fig. 5 (a) and (b) represent an unsaturated transformer which has a comparatively large voltage E_1 for a small current I_0, and which is therefore equivalent to a large inductance. The same circuit with the transformer highly satu-

rated is represented in Fig. 5 (c), when I_0 is much larger in proportion to E_1 and so the transformer is equivalent to a low inductance.

The vector diagrams of Fig. 5 which have been shown to apply to the circuit in Fig. 3, all give the following relation:—

$$E^2 = (E_1 - S\,I_m)^2 + S^2 I_w^2$$

in which,

E = Impressed e.m.f.
E_1 = Voltage across the transformer
I_m = Magnetizing or wattless component of current
I_w = Power component of current
S = Capacity reactance of condenser.

In practical cases this formula will be subject to the limitation that neither the current nor the voltage of the circuit will be true

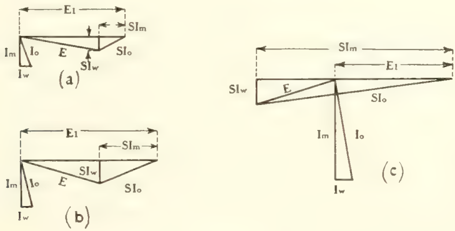


FIG. 5

sine waves, and cannot strictly be represented by a vector diagram. This is due to the fact that a condenser in a circuit exaggerates any slight variations from a true sine wave which there may be in the original generator wave form. However, no very great error is made by assuming that the current and e.m.f. of the circuit can be represented by equivalent sine waves.

The same relation which was found for the circuit of Fig. 3 exists for the three-phase generator circuit in Fig. 2, if E is equal to the star voltage of the generator (from line to neutral), and S is the capacity reactance of all three phases of the generator windings. This is shown as follows: Let P be the voltage from the neutral point N to ground. The average voltage at any instant applied to each phase of the windings, considered as a condenser of 3 S ohms capacity reactance, is the vectorial sum of:—

P and ½ E for phase *1*
P and ½ E cos 120 degrees for phase *2*
P and ½ E cos 240 degrees for phase *3*

The total charging current, then, is:—

$$I_0 = \frac{3P}{3S} \text{ combined with } \frac{1}{3S}\,E(1 - [illegible] - [illegible]) = \frac{P}{S}$$

The resultant of the three components of E at 120 degrees to one another will always be zero; hence, $P = SI_0$.

Thus the vector diagrams of Fig. 5 apply exactly to the case of a generator tested for grounds by means of a meter transformer. The voltages E_1, across the transformer, and SI_0, between N and ground, are balanced by E, the star voltage of the generator.

Let V be the resultant of E_1 and SI_0, which acts under steady conditions as a counter-e.m.f. to the generator star voltage E.

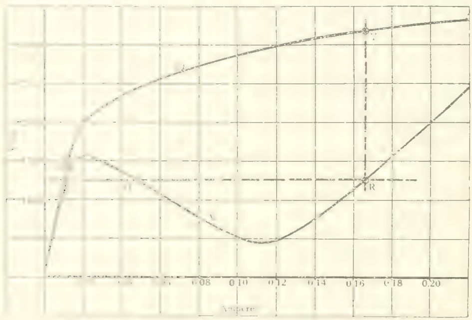


Fig. 6

Then, if it be assumed that the current and e.m.f's. can be represented by simple harmonic (sine) waves, the following equation will be obtained:—

$$V = \sqrt{(E_1 - SI_m)^2 + S^2 I_w^2}$$

Values of the resultant counter-e.m.f. V as obtained from this equation are plotted in Fig. 6 against values of I_0, for a particular test in which a 2 200/110 volt voltage transformer was used in connection with a 1 250 k.v.a. 2 200 volt three-phase generator, having an equivalent capacity reactance of 26 500 ohms. The curves for I_w, I_m, and I_0 of the transformer are given in Fig. 7. The effect of capacity and inductance in the circuit is to cause a marked dip in the curve of V in Fig. 6. This is accounted for by the minus sign in the equation. The curve shows that there are three values of I_0, namely, P, Q, and R, which satisfy the condition that the vectorial sum of the counter-e.m.f's. of inductance

and capacity shall be equal to the generator star voltage which is 1 270 volts. The vector diagrams for these three cases are Fig. 5 (a), (b) and (c).

On closing a circuit of this kind, which has capacity and inductance, transitory current oscillations are set up, the amplitude of which depends on the point of the impressed e.m.f. wave at which contact is made. The frequency of the oscillations is such that the total e.m.f. in the circuit due to them is always zero. In other words, the frequency of these oscillations depends on the natural period of the circuit. A current at the generator frequency will flow at the same time, such as to produce a counter-e.m.f. of capacity and inductance which will balance the impressed

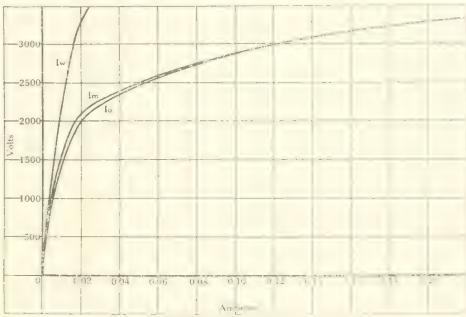


Fig. 7

voltage. Thus the resultant wave form is greatly distorted at first from the value which it finally takes.

As the transitory oscillations die out, the current takes a steady wave form at the generator frequency, and then adjusts itself to one of the three values, *P*, *Q*, or *R*. At this stage, if I_0 is just below the value *P*, *E* will increase it. If I_0 is just above *P*, the resultant counter-e.m.f. *V*, which corresponds to equilibrium at that value of exciting current, is greater than *E*, and this will cause I_0 to drop to *P*. Thus conditions are stable at *P*. The same is true at *R*. The corresponding values of E_1 are *X* and *Y*, the double voltages observed.

No voltage is observed corresponding to *Q*, because this point represents unstable equilibrium. If I_0 is at any time a little greater than *Q*, *V*, the counter-e.m.f. for stable conditions at this value of exciting current, is less than *E*, and I_0 increases to *R*.

Similarly, if I_0 is just less than Q, V is greater than E, and so I_0 is reduced to P.

The capacity reactance, S, was measured by connecting a voltmeter as in Fig. 1, using the formula:—

$$I^2 = E^2 \div (R^2 + S^2)$$

where, I is the voltmeter current, R, the voltmeter resistance, and E, the generator star voltage. This method of finding the capacity reactance was checked by applying an external voltage between ground and the winding of the generator while at standstill, and measuring the charging current. The same value of S was obtained by both methods. The values of the various quantities observed during the test were in close agreement with those calculated from the curves of Fig. 7.

A few practical hints may be useful to those who would wish to observe this phenomenon of double voltages. Connect up a generator and transformer as in Fig. 2. Start with a low generator voltage and gradually raise it, without breaking the contact to ground. Tabulate V, the generator star voltage, and E_1, the transformer voltage; V can be taken as high as its maximum point, just above P in Fig. 6, and then the needle of the transformer voltmeter will suddenly swing across to a value on the curve above Y. The generator voltage should now be adjusted to a little below this point. Make contact to ground a number of times with a sharp tap, and sometimes a low voltage will be observed; sometimes a high one. Precaution should be taken against receiving a shock, as the voltages in such circuits are often much higher than anticipated.

When double voltages are observed on a generator, the voltage between neutral and ground is SI_0 as in Fig. 5. This is approximately equal to the transformer voltage plus the star voltage. However, parts of the winding are at a voltage to ground equal to the transformer voltage plus the line voltage. Thus the generator mentioned in the first paragraph was under a strain of 3 600 + 2 400 = 6 000 volts between the windings and ground. From tests made with several generators of different sizes, it has been found that the strain on the insulation when double voltages are produced, may amount in ordinary cases to nearly three times line voltage. This is a dangerous amount for machines which have been in service for a considerable time. It may therefore be stated that, in general, it is not advisable to use a voltage transformer in testing for grounds.

GROUPING OF CURRENT TRANSFORMERS—Concl.

HAROLD W. BROWN

OPEN DELTA, DELTA AND Z-CONNECTIONS

IN the November issue Y and reversed-V connections were discussed. There are three remaining groupings in common use on three-phase circuits. The following are their principal applications, together with some modifications:—

OPEN DELTA OR V-CONNECTION

There are two transformers for this connection which have two leads connected separately to the two transformers and one common lead. The common lead connects to the upper terminal of one and the lower terminal of the other transformer, and has a current 1.73 times the current in either of the transformers. This connection is different from the reversed-V connection,* in that with the reversed-V connection the common lead is connected to the same end of each transformer, and the current in the common lead is equal to 1, instead of 1.73, times the current in either transformer. There is a phase difference of 90 degrees between the currents in the two cases.

With the open-delta connection the current in the common line at 100 percent power-factor is in phase with the voltage between the two lines to which the transformers are connected. This fact makes such a connection suitable for use with a voltage compensator or with a single-phase wattmeter, watt-hour meter, or power-factor meter, where this meter is to give indications for the entire three-phase system. Fig. 11 (a) represents a pair of open-delta-connected current transformers together with the following apparatus connected to them:— Polyphase wattmeter and watt-hour meter; single-phase power-factor meter (or single-phase wattmeter or watt-hour meter); voltage compensator (or other voltage regulating device); and two single-phase relays (or trip coils). The relays and each circuit of the polyphase meters are connected each to a single transformer. The single-phase power-factor meter and compensator are connected in circuit with the two transformers.

In addition to this apparatus, single-phase apparatus may be inserted at points *L* and *R* in series with the left hand and right

*Illustrated on pages 1 024 and 1 025 of the November issue.

hand transformers respectively and at point RL in series with both transformers. At the point RL the current is the same as that which flows through the power-factor meter and compensator; is 1.73 times the current in either transformer, and is in phase with the voltage between the two outside lines. The ammeter cannot be inserted at this point to measure the current in the middle line

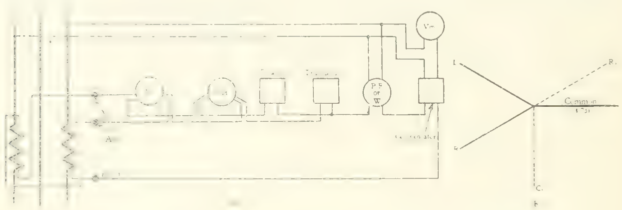


FIG. 11 — OPEN [illegible] V CONNECTION [illegible] AND [illegible] DIAGRAM

as is the case with the reversed-V connection referred to above. The vector diagram of Fig. 11 (b) shows the phase relation of the various currents. If the common line were connected to the same end of each transformer (reversed-V connection) the currents in the two lines and in the common line would be represented by L, R_1, and C_1; but with one transformer reversed they are represented by the lines L, R and the *common* line, respectively.

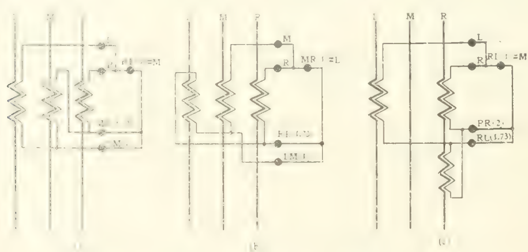


FIG. 12 — [illegible] OF REVERSED-V AND OPEN-DELTA CONNECTION

If it is desired to measure the current in each of the three lines or to obtain current in proportion to that in each line, a transformer may be added as in Figs. 12 (a), (b) or (c). In (a) the left and right hand transformer currents pass through the points L and R and the resultant current from the two (which is equivalent to the current in the middle line M) flows through

RL (1). The figures in parentheses, in this and following diagrams, indicate the ratio of current in any given lead to the current in any one of the transformers, assuming that the currents are the same in all transformers. Apparatus connected at *MR*, Fig. 12 (a), has a current in phase with the voltage between the middle and the right line and is suitable for a voltage compensator or single-phase power-factor meter, wattmeter or watt-hour meter as indicated in Fig. 11. Similarly, in Fig. 12 (b) the three ammeters may be connected at *M*, *R* and *MR*, and the compensator or single-phase power-factor meter at *RL*. In Fig. 12 (c) the ammeters are at *L*, *R*, and *RL* (1), and the compensator or power-factor meter at *RL* (1.73). In both Figs. 12 (a) and (b) there is one transformer on each line, and this is usually preferable to the arrangement in Fig. 12 (c) which has one transformer on one line

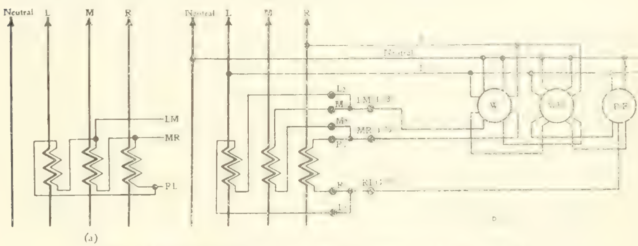


FIG. 13—DELTA CONNECTION OF [illegible]

and two on another, because transformers can usually be arranged more easily in the symmetrical form of Fig. 12 (a) or (b). Instruments can be connected at *LM* in Fig. 12 (a) and (b) or at *RR* in Fig. 12 (c), but they will not have the right phase relation for a power-factor meter or compensator. The current in *RR* is exactly twice that in *R* of Fig. 12 (c), whether the currents are balanced or not.

DELTA CONNECTION

With this connection each lead is connected to the top and bottom of two transformers and carries a current 1.73 times that in any one transformer. The elementary connections are shown in Fig. 13 (a). This connection is used most commonly on three-phase four-wire circuits for wattmeters, power-factor meters, and watt-hour meters; Fig. 13 (b) shows the connections* to this ap-

*If the voltage connections are on the low-tension, six-phase side of the power transformers and the current connections are on the high-tension, three-phase side, see paragraph "Current Transformers in High-Tension Circuits," p. 1029, and Fig. 8, p. 1030, November, 1911.

paratus and also the points where other apparatus may be connected. At L_1 and L_2 the current is in phase with that in the left hand line; at M_1 and M_2 with that in the middle line, and at R_1 and R_2 with that in the right hand line. At the points *LM, MR* and *RL* the resultant of the two transformer currents has a value 1.73 times that in any transformer. Single-phase apparatus, such as ammeters, may be connected at L_1 or L_2, M_1 or M_2, and R_1 or R_2, and apparatus requiring an open delta connection may be at *LM, MR* or *RL*. It is interesting to note that *three* compensators may thus be connected in the circuit so as to compensate for line drop and obtain the resulting voltages at a distant point between *each* pair of lines; whereas with the open-delta connection only *one* such compensator can be used, and therefore only one voltage measured. It is not possible to have Z-connected relays with delta-connected transformers without an additional transformer (illustrated in Fig. 16). Neither is it possible to have three ammeters with each of two in series with one transformer and the third in series with both of the preceding, but this connection is unnecessary inasmuch as the three meters may be at L_1, M_1, and R_1, or at L_2, M_2, and R_2. Thus a delta connection should be adaptable to practically all apparatus except Z-connected relays. Either two or three relays may be used with this connection but each relay must be in series with a single transformer.

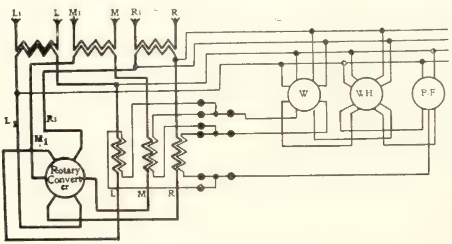


FIG. 14—DELTA CONNECTION ON SIX-PHASE DIAMETRICAL CIRCUIT

The number of leads from the transformer to the instrument is sometimes of importance. With a delta-connection to wattmeters, watt-hour meters, and power-factor meters as shown in Fig. 13, only three leads are required. If in addition three ammeters are to be connected, each to measure the current in one line, five leads are required.

Measurements can be made for a six-phase diametrically-connected rotary converter as shown in Fig. 14, with delta-connected current transformers. The current transformer connections

are exactly the same as in Fig. 13, and other apparatus can be added in a similar manner. Although there are six main leads from the power transformers to the rotary converters, only three current transformers are required for all measurements of current and power, because in each case there are two lines connected to the same power transformer, and which are therefore in series (i.e., L is in series with L_1, M with M_1, and R with R_1). The

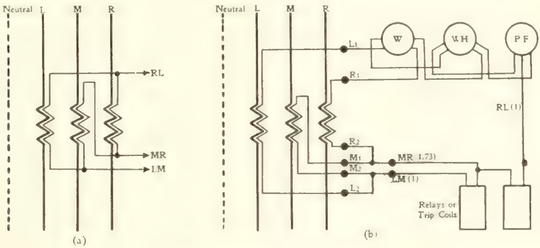


FIG. 15—Z CONNECTION

voltage connections in the six-phase arrangement are different from those in the three-phase four-wire connection, as is shown in Fig. 14.

Z-CONNECTION

With the Z-connection there are three leads, each connected to two transformer terminals. One lead is from the top of one pair of transformers and another from the bottom of another pair; each of these has a current equal to the current in either of the transformers. The purpose of this connection is to provide protection for a three or four-wire circuit by means of only two relays or trip coils. One relay (or trip coil) is connected to each of these leads. The common return is connected to both relays and has 1.73 times the current in any one of the transformers. The elementary connections are illustrated in Fig. 15 (a). The leads to the two relays are LM and RL, and the common return is MR.

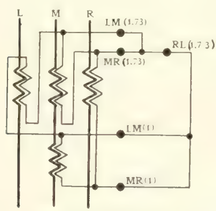


FIG. 16—COMBINATION OF DELTA AND Z CONNECTION

A relay, wattmeter, watt-hour meter and power-factor meter may be connected as in Fig. 15 (b). Other single-phase apparatus should be connected in the left hand line at L_1 or L_2; in the middle line at M_1 or M_2, and in the right hand line at R_1 or R_2. Apparatus requiring an open-delta connection, such as a compensator or power-factor meter, should be connected at MR. Its current

is then in phase with the voltage between lines M and R and is 1.73 times the current in either transformer. In a three-wire circuit, ammeters may be inserted at L_1, R_1 and RL. Only four leads are then required from the transformers to the meters. On a four-wire circuit the ammeters may be at L_1, M_2 and R_1. Five leads are required for a four-wire circuit if ammeters are added.

The wattmeter, watt-hour meter and power-factor meter in Fig. 15 do not give correct measurements when there is current in the neutral or ground return. If these meters are to be connected in with relays on a three-phase four-wire circuit it is possible to combine a Z and delta connection as in Fig. 16 by the addition of one transformer. With such a connection the wattmeter circuits may be inserted in $LM(1.73)$ and $MR(1.73)$ and the currents will have the same value and phase relation as in Fig. 13 or 14. The relays may be inserted at $MR(1)$ and $LM(1)$ and they offer the same protection as with a regular Z-connection. Thus, with these four transformers all the requirements of a Z and delta-connection are provided. Together with this, all other combinations can be obtained, such as a V-connection for a compensator, and connections for ammeters on single transformers.

CONCLUSION

One of the purposes of this paper is to indicate that it is seldom necessary to install additional transformers on account of interferences between different kinds of apparatus. A delta-connection is required for some apparatus on a three-phase four-wire circuit and a Z-connection is required for complete overload protection; but nearly every other combination of apparatus can be connected to either delta or Z-connected transformers. If neither a delta nor a Z-connection is required, it is usually possible to obtain all of the necessary phase relations with only two transformers. (Figs. 12 and 16 illustrate exceptions to this statement.) It is nevertheless desirable, in many cases, to provide additional transformers where there is too much apparatus for one set.*

Only a single type of wattmeter, watt-hour meter, power-factor meter, etc., are here shown, but they may be readily replaced by other types of apparatus. The polyphase power-factor meter represented in all cases is the one having a winding for *each* phase. If it is replaced by a power-factor meter having only a single current winding, its current circuit may be treated in the same manner as an ammeter or other single-phase apparatus.

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*See article on this subject in the JOURNAL for July, 1911, p. 642.

CHARTS FOR DETERMINING EFFICIENCY AND REGULATION

J. F. PETERS

THE calculations for efficiency and regulation of a piece of electric apparatus by ordinary methods involve considerable work and time, so that any scheme that tends to make the calculations easier and shorter is of great assistance to the engineer. The efficiency and regulation charts described in the present article were made up with this end in view and with their range of application will doubtless be found a great help in making rapid determinations of efficiency and regulation of apparatus such as transformers, or transmission systems as a whole, for different loads and power-factors.

EFFICIENCY CHART

The efficiency chart, which is shown in Fig. 1, is not universally applicable, but can be used in all cases where the total loss consists of two components—one a constant loss and the other a loss which varies as the square of the load. It is particularly applicable in calculating the efficiency of transformers, in which case the iron loss is the constant and the I^2R or ohmic loss the variable quantity. When using the chart to determine efficiencies of a rotating machine the sum of the iron loss, field I^2R loss, friction, and windage should be considered as a constant loss for all loads; the accuracy of the chart for such purpose then depends, of course, on how nearly constant these losses are for various loads.

By definition, efficiency is the ratio of the net power output to the gross power input.

When e = the efficiency of a machine, in percent,

$$e = 100 \left[\frac{\text{Output}}{\text{Input}} \right] = 100 \left[1 - \frac{\text{Loss}}{\text{Input}} \right]$$

It is convenient to have this formula expressed in terms of output since the latter is a fixed quantity.

When based on output, percent efficiency equals

$$e = 100 \left[1 - \frac{\text{Loss}}{\text{Output} + \text{Loss}} \right]$$

or, expressed in percent losses,

$$e = 100 - \left[\frac{100 \times \text{total percent loss}}{100 + \text{total percent loss}} \right]$$

It is necessary to separate the constant loss from the variable loss in calculating the efficiencies for different loads.

Let $P =$ full load output;

$I^2R =$ loss which varies with the square of the load;

$L =$ loss that is constant for all loads.

Then total percent loss at full load,

$$= \left\{\frac{I^2R}{P}\right\} + \left\{\frac{L}{P}\right\}$$

$=$ percent I^2R loss $+$ percent constant loss.

Total percent loss at $1/2$ load.

$$= \frac{\left(\frac{I}{2}\right)^2 R}{\frac{P}{2}} + \frac{L}{\frac{P}{2}}$$

$= 1/2 \times$ percent I^2R at full load $+ 1/2 \times$ percent L at full load.

For any load $\frac{n}{m}$ the total percent loss becomes $\dfrac{\left(\frac{n}{m} I\right)^2 R}{\frac{n}{m} P} + \dfrac{L}{\frac{n}{m} P}$

$= \frac{n}{m} \times$ percent I^2R at full load $+ \frac{m}{n} \times$ percent L at full load.

It will be seen that the multiples affecting the two component losses at a given load are the ratio of the given load to full load and its reciprocal, expressed as common fractions, namely, $(n \div m)$ and $(m \div n)$.

The construction of the chart is as follws: Two parallel scales representing percent I^2R and percent constant losses at full load are located at a convenient distance apart, and scales representing the efficiencies for different loads are located between and parallel to these loss scales, so that the distances from the I^2R and constant loss scales to the efficiency scale under consideration, have the same ratio as the multipliers affecting the losses at this load. The divisions on the I^2R and constant loss scales are equally spaced, while on the efficiency scales the divisions decrease in length with decrease of efficiency, due to the correction $(100 \times \text{percent loss}) \div (100 + \text{percent loss})$.

Examples—To show how the chart may be used, consider the following examples. Given a five k.v.a. distributing transformer having an I^2R loss of 1.85 percent at full load and an iron loss, or constant loss of 0.9 percent at full load, to determine efficiencies, place a straight edge across these values on their respective scales

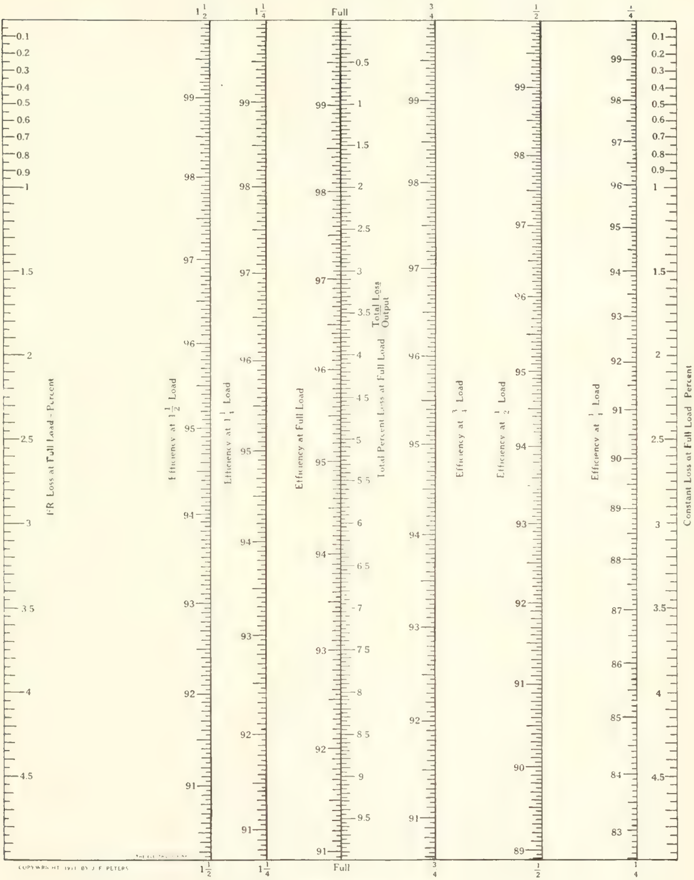


FIG. 1—EFFICIENCY CHART

To obtain efficiency at any given load, lay a straight edge across the given I^2R and constant loss values and read the efficiencies at the required loads on the corresponding scales. The total percent loss at full load may also be obtained simultaneously.

To obtain the variable and constant components of the loss and the corresponding total percent loss at full load, when efficiency values corresponding to any two loads are given, place a straight edge across the two given points and read the required percent losses on their respective scales.

Likewise, if the efficiency corresponding to a given load is known and the constant loss, for example, is known, the variable loss corresponding to the given load may be read from the I^2R scale, and the total percent loss from its scale.

and the following values will be obtained:—

96.75 at 1½ load	97.45 at ¾ load
97.05 at 1¼ load	97.3 at ½ load
97.3 at full load	96.1 at ¼ load

Again, for example, suppose the segregated losses are required of a five k.v.a. transformer having any two of the above efficiencies known; the percent losses may be determined on the respective scales by placing the straight edge on those efficiency values.

REGULATION CHART

By definition, regulation is the percent increase in the voltage as the load is decreased from its normal value to zero. This may

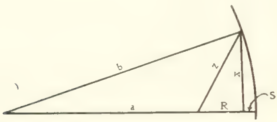


FIG. 2

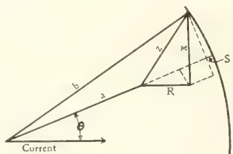


FIG. 3

a = full load voltage; b = no load voltage; R = resistance drop or IR drop, or voltage drop due to ohmic resistance; X = reactance drop or voltage drop due to inductive resistance; Z = impedance drop or voltage drop due to ohmic plus inductive resistance, combined at right angles, $= \sqrt{R^2 + X^2}$; θ = angle by which current lags behind full load voltage. Then, $S = b - (a + R)$. It may be noted that percent IR drop is equal to percent I^2R loss.

be shown graphically by Figs. 2 and 3, the former is for 100 percent power-factor and the latter for any other power factor.

Regulation at 100 percent power-factor $= b - a = R + S$;

Thus:

$$b = \sqrt{(a + R)^2 + X^2} = a + R + S;$$

$$X^2 = S(2a + 2R) + S^2, \text{ and}$$

$$S = \left[\frac{X^2 - S^2}{2a + 2R}\right]$$

Since regulation is expressed in percent, it is convenient to express *a*, *R* and X in percent.

By definition, $a = 100$ percent; R = percent I^2R;

$$\text{then } S = \frac{X^2 - S^2}{(200 + 2 \times \text{percent } I^2R)}$$

$$R + S = \text{percent } I^2R + \frac{X^2}{200} \text{ approximately.}$$

This is accurate enough for practical purposes—for instance, with a reactance of 5 percent and I^2R loss of 1.5 percent;

$$\text{percent } I^2R + \frac{X^2}{200} = 1.625,$$

$$\text{percent } I^2R + S = 1.6232, \quad \text{a very slight difference.}$$

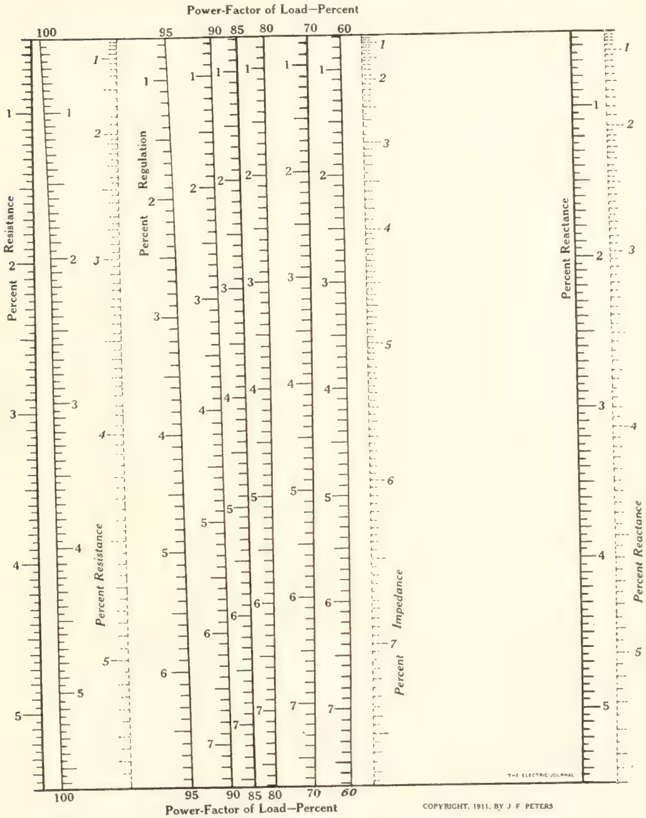


FIG. 4—REGULATION CHART

To obtain the regulation for a load of any power-factor, lay a straight edge across the given percent resistance and reactance values, and read the regulation at various power-factors of load on the respective scales.

To obtain the resistance and reactive components when the regulations corresponding to two power-factors are given, place a straight edge across the given points and read the required components on their respective scales.

Values for power-factors between those for which scales are given can be closely approximated by interpolation.

The broken line scales are primarily for determining, by means of a straight edge, the reactance when the impedance drop and resistance drop are known. Obviously, with any two of these three factors given, the third can be obtained directly from the broken line scales.

In Fig. 3, by definition, θ = angle by which current lags behind full load voltage; while the other values correspond to those of Fig. 2. Then $\cos\theta$ = power-factor of the load, and regulation = $R\cos\theta + X\sin\theta + S$ = percent $I^2R\cos\theta$ + percent $X\sin\theta$ +

$$\frac{(\text{percent } X\cos\theta - \text{percent } I^2R\sin\theta)^2}{200}\text{, approximately.}$$

The regulation chart, Fig. 4, consists of two parallel scales representing the percent resistance drop (percent I^2R) and percent reactance drop, located at a convenient distance apart, with scales representing the regulation at different power-factors between them. The three scales in light dotted lines are for obtaining the reactance when the resistance and impedance values are known. They are not to be used for determining regulation.

Example—To illustrate the use of the chart, consider a machine having three percent resistance drop and five percent impedance drop. Place a straight edge across these values on the dotted resistance and impedance scales and four percent reactance will be read on the dotted reactance scale. Upon placing the straight edge across these values—three percent resistance, four percent reactance—on their respective scales on the full lines, the following values will be obtained:—

3.1	percent at	100	percent power-factor
4.15	percent at	95	percent power-factor
4.45	percent at	90	percent power-factor
4.65	percent at	85	percent power-factor
4.8	percent at	80	percent power-factor
4.95	percent at	70	percent power-factor
5.	percent at	60	percent power-factor

The regulation charts contain a small error which, however, for practical purposes, is inappreciable.

A straight edge made of some transparent material, such as celluloid, will be found convenient for use in connection with these charts. The user can then see at a glance the approximate reading desired without shifting the straight edge. Another convenient arrangement is to draw a hair line on a transparent rule or triangle, using this for the reference line. This avoids trouble due to shadows in case of poor lighting conditions. A rectangular notch cut in the straight edge near one end, to slightly more than the depth of the hair line, will make it possible to fix one of the two known points by placing a pencil on the exact reading and adjusting the straight edge so that the pencil point will be in one corner of the notch and therefore on the hair line of the straight edge. The proper setting can then be obtained directly by swinging the straight edge around this point as a center, a much simpler operation than that of setting to two points simultaneously.

AN AUTOMATIC PUMP GOVERNOR AND WATER LEVEL REGULATOR

A. C. LASHER

Chief Electrician, Central of Georgia Railway

A FIVE INCH low head centrifugal pump, driven by a seven horse-power direct current motor, is used to supply raw water to the 85 000 gallon settling reservoir of a small filter plant. The motor speed is varied from 650 to 1 000 revolutions per minute by means of shunt field control, and the pump discharge varies from 100 gallons per minute minimum to about 900 gallons per minute maximum flow. A two-stage turbine pump, also motor driven, with provision for hand adjustment of speed, draws from this reservoir and discharges through pressure filters into the general service mains. Owing to the character of the service, the quantity of water pumped fluctuates considerably throughout the twenty-four hours. To obtain the most efficient service from the settling reservoir it is essential that the reservoir be kept at a uniform level and always as full as possible.

In laying out this plant, it was intended to adjust the field circuit of the motor driving the low-pressure pump, so as to provide slightly in excess of the demand of the high-pressure pump, and by means of a tank float, controlling a magnet switch on the former unit, stop or start the pump as the float rose or fell a predetermined distance above or below the proper level. It was found, however, that the service required this motor to run at or near its highest speed the greater part of the time, also that to start the unit with the rheostat set for the higher speeds resulted in a severe strain on the motor, owing to the weakened condition of the field. The difficulty was overcome and the water level of the settling reservoir maintained practically uniform throughout the entire range of the low-pressure pump, by means of an automatic speed regulator, as follows:—

A belt was run from a point on the shaft of the pump near the flange coupling, to a pulley mounted with the remainder of the appliance at a convenient position on the wall and over the edge of the settling reservoir. This pulley turns a worm and gear, and by means of a crank and rod, operating from the gear, provides reciprocating motion with a ratio in speed as compared to the motor shaft of about 1 : 800. Movement is transmitted through the rod to the rocker *C*, Fig. 1, to which are at-

tached two pawls, one acting right-handed and the other left-handed. These two pawls move back and forth over corresponding ratchet wheels, the ratchets also being arranged right and left. The ratchet wheels are secured rigidly to a common shaft, but are spaced a short distance apart so that each can operate from its corresponding pawl without interference from the pawl on the opposite side. To the shaft which carries the two ratchet wheels is also secured a sprocket wheel. A chain serves to connect this sprocket wheel to another similar one, which is attached to an extension on the field rheostat shaft.

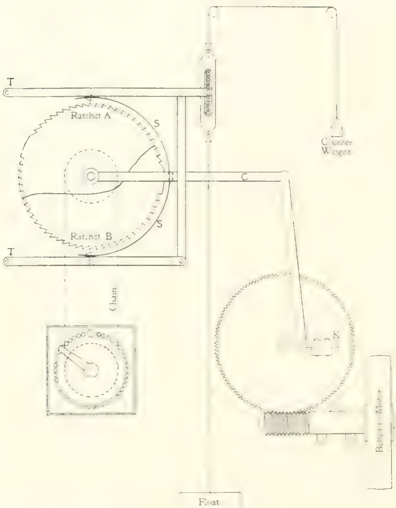


FIG. 1—DIAGRAM OF PUMP REGULATOR

Normally, the two pawls are held away from the ratchets by means of the slight spring in the part *S*. Motion of the float upward or downward is transmitted by means of the small chain, passing over the small pulleys to the counterweight and to the clutch mechanism over the pawls. The clutch mechanism is arranged to move freely about the pivoted points *T*, when under the influence of the cord carrying the float. It will be observed that pressure will be brought to bear on one or the other of the pawls, according to whether the float is above or below its neutral position, and, therefore, the reciprocating movement will be transmitted by means of the ratchet wheel and the sprocket and chain to the rheostat which is connected in series with the shunt field coils of the motor. If the water level becomes low the float falls, causing the upper pawl to engage the ratchet and turn the rheostat arm in a clockwise direction, thereby cutting in more resistance, weakening the field of the motor and causing the pump to increase in speed. Conversely, if the water level

becomes high the float rises, the lower pawl engages its ratchet and turns the rheostat arm in a counter-clockwise direction, strengthening the motor field and causing the pump to diminish in speed. The rate at which the change of speed is brought about can be modified by means of the adjustable crank *K*, since by changing the effective radius of the crank the pawls may be made to engage every tooth, or to skip one or more, as desired.

It will be observed that a portion of the circumference of each of the two ratchets is without notches or teeth. This portion of the wheel may be adjusted with reference to the rheostat arm so as to limit the travel of the latter to a trifle less than a full circle, and thus avoid interference of the arm with the stop at the upper part of the circle. Confusion of this character would result only in case of a sudden fluctuation of load tending to vary the speed of the motor beyond its limit in either direction.

While the general scheme is shown in Fig. 1, the notches on the rim of the ratchet wheels are more numerous than is indicated by the sketch, and the field rheostat contains a much larger number of steps. The settling reservoir, while primarily considered as one, is divided into two parts. The larger basin of 60 000 gallons capacity receives water from the pump and discharges through an overflow gate into the smaller basin which has a surface area of about 450 square feet. The regulator, therefore, has to do only with the level of the smaller basin. A variation in water level of three inches serves to set the ratchet wheels in motion, yet there is often a variation of six or eight inches before normal water is restored.

The adjustable crank was set as short as possible so that the pawls advance but one notch at a time. This movement gives a change of but one-half of a point on the rheostat and therefore the rheostat arm will advance or recede one point in from one to two minutes, depending upon the motor speed. For example, the change from 800 to 900 r.p.m. will take place in about twenty-five minutes, corresponding to a change of pump discharge from 650 to 800 gallons per minute. Fluctuations greater than this in the time specified are of rare occurrence. Throughout portions of the day when the demand is exceedingly variable, the rheostat arm is continually in motion, but if the demand becomes uniform for a period of one-half hour or more the regulator slowly brings the low pressure pump to that speed which will maintain the proper level. This arrangement has been in use about a year, and has proven entirely satisfactory for the work required.

ELECTRIC SIGNALING BY TROLLEY CONTACTS

IN the article entitled "Recent Developments in Signaling for Electric Railways", which appeared in the October issue of the JOURNAL, a paragraph was devoted to "Trolley Contact Signals", the major portion of the article, however, being devoted to track circuit signaling. The following comment should thus prove of interest as bringing out more in detail the possibilities and also the limitations of the trolley contact type of signals.

NACHOD SIGNAL COMPANY
C. P. NACHOD, General Manager
929 Chestnut Street

PHILADELPHIA, PA., October 21, 1911.

THE ELECTRIC JOURNAL,
Editorial Office,
Pittsburg, Pa.

GENTLEMEN:—In your excellent periodical for October, page 848, in an article, "Recent Developments in Signaling for Electric Railways," by Messrs. McCready and Harrington, certain statements are made regarding trolley contact signals that in justice to them require modification.

The disadvantages of trolley contact signals are that the signals, being changed at the instant of passing the trolley contactor, the trolley wheel must be on a live wire at that time. Since these conditions may not always obtain, there must be an affirmative indication that the signals have been changed by the passage of the car, and this is attained by placing the signal aspect in advance of the trolley contact, so that the motorman can see that he has properly affected the signals. This requires additional discipline on the part of the train crew, but as it requires discipline to observe or read a signal set by another train, that same discipline should be logically extended to assure that signals have been set by one's own train. In other words, is it not just as important that a motorman should leave signals as that he should observe the signals of another? This is the discipline that a trolley contact signal system requires over any system using the rails for signaling, and actuated by power other than the motive power of the car.

It is true that a trolley contact system would give absolutely no protection against a broken rail, but this trouble does not seem to be serious with electric railways, and it is also true that all track circuit signals, having

one rail undivided, of which there are many miles in operation, will not detect broken rails, as the writers state.

A short insulated track section, or rather two of them in series, at the ends of the block, one for clearing and one for setting, have been proposed as a means of signal control; but the writer cannot advocate these, since an accidental short-circuiting of the clearing section, which could easily happen, would clear the signals with a car in the block. A trolley contactor, on the other hand, can be constructed to have very high electrical insulation, thus making the liability to break-down very remote.

A trolley contact signal may be interlocked through the usual switch boxes so that an open switch will be indicated by signals. A trolley contactor can be located on the spur track such that a car within fouling distance would set signals, indicating its presence.

Regarding the statement of the motorman unwittingly passing a signal at night in case his trolley should not operate the signal, this can easily be prevented by using a red marker light, burning at all times, as has generally been recommended.

Regarding a statement that a trolley contactor cannot be depended upon for high speeds, the Chicago & Milwaukee Electric Railroad Company stated that a contactor they have in use was perfectly successful for speeds up to 55 miles an hour with a four-car train, four trolleys up.

The writer is of the opinion, moreover, that one of the new track circuit developments in permissive signaling has been brought about by the effective permissive operation obtained for several years through contact signals.

For more complete discussion on contact signals, reference is made to the *Signal Engineer*, May, 1911, page 200, and to a specific type of contact system, same periodical, February, 1911, page 49.

Yours truly,

CARL P. NACHOD.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

655—Two-Phase Generator Changed to Three-Phase—We have a two-phase, 60 cycle, 2 200 volt alternating-current generator of the revolving field type, having 16 poles, 96 slots, two coils per slot. We desire to take three-phase current from this machine by connecting the middle point of one of the two-phase windings with the 86 percent point of the other winding, thereby giving a two- to three-phase connection. This machine is rated at 59.1 amp. per phase, giving 260 k.v.a. We figure that with the above connection and the same current in the armature the machine will have a capacity of 225 k.v.a. Please advise whether you see anything wrong with the above modification of connections. R. A. L.

The scheme of connecting the two-phase generator so as to obtain three-phase power is correct. It should be borne in mind that the generator, after having been connected as proposed, may not run satisfactorily in parallel with ordinary Y-connected generators. Furthermore, the voltage of the generator, when it is carrying loads, may be slightly unbalanced, due to the difference in ohmic and inductive drops between the different terminals.

J.B-W.

656—Rewinding Fan Motor—An old style four-pole, 12-inch fan motor, rated at 115 volts, 60 cycles and wound with No. 24 wire, is found to run at only one-eighth speed when connected to the circuit. As the motor appeared to have been rewound for some other voltage or frequency, I decided to again rewind it. The stator was found to have 1 248 turns. The formula $n = \frac{V \times 10^8}{4.4\ f\ B}$ was applied, in which n = primary turns, B = magnetic lines per sq. in. (assume 10 000 sq. in. for a total of eight sq. in. with four poles), V = volts (assume 105), f = frequency in cycles per second. From this a value for n of 5 048 turns is obtained. Please point out the error in this calculation. H. W. H.

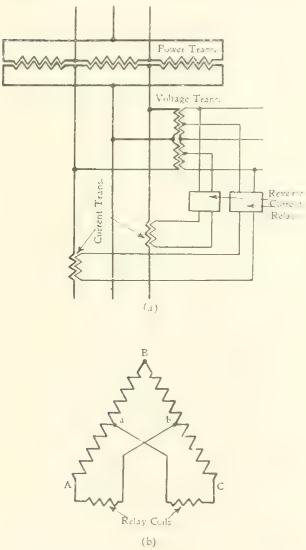
The fan was evidently wound for 55 volts and was arranged to run on the high speed with two coils in series and two sets in parallel, the four coils being put in series for the low speed. The operation at one-eighth speed may have been caused by a short-circuit or other trouble within the winding. According to the above formula, which is correct provided the terms are used correctly, the flux density should be 16 700 lines per sq. in. or 33 450 per pole. This is a much better value to use than 10 000, because it gives a better torque. We believe a problem of this sort is best handled by calculating for one pole and then getting the final results according to the number of poles. For instance it is desired to rewind this fan for 105 volts and connect all poles in series. Then, using volts per pole, flux per pole, and turns per pole:—

$$\text{Turns per pole} = \frac{105 \div 4 \times 10^8}{4.44 \times 60 \times 33\,450}$$

= 295 turns per pole.. If the motor is to be connected two poles in series and two in parallel as before, then twice the turns per pole must be used, since the volts per coil will be twice as great. In the second case the same size wire should be used and in the first, three sizes smaller. That is, the cross-section of the primary copper should be maintained the same for any voltage. The fan should take about 70 watts. O. S. J.

657—Loading of Voltage Transformers—Two 200 watt voltage transformers are connected in open delta on a three-phase circuit; taps are taken out as shown in Figs. 657 (a) and (b) for operating potential coils of reverse current relays. What amount of energy per coil corresponds with the full rating of the voltage transformers? E. B.

The voltage coil of a reverse current relay is in effect practically a non-inductive load. With two relays connected as shown, the current in one-half of each transformer will be A amperes, and in the other half will be $\sqrt{3} \times A$ amperes, where A is the current taken by one relay. The heating effect of these currents is equivalent to a current of 2A amperes in the whole winding; and a load of 100 watts per coil represents full load on the transformers. With two transformers connected as shown, the current drawn by one relay passes through the winding of one transformer and one-half the winding of the second transformer. Superposed on two-thirds of this is an equal current at an angle of 60 degrees. The *CR* drop in each transformer will be twice the drop in a single transformer carrying a single relay. In other words, so far as compensation is concerned, 100 watts in each represents full load on the transformer. The voltage applied to a reverse current relay needs to be approximate only, and the load on the transformers is limited by heating rather than ratio error. As voltage transformers are usually designed with a low copper loss in order to get good regulation, they will stand a considerable overload without undue heating. W. R. W.



Figs. 657 (a) and (b)

658—Effect on Operation of Motor of Changing Span of Coils—Will you please inform me what effect it has on the performance of a direct-current motor to change the span of the coils by one slot, that is for example put the coils in slots 1 and 18 instead of 1 and 19, the total number of slots being 41. W.J.R.

The effect of reducing the span of the coil is either to chord the coil or increase the chording. In the example given, a throw of 1 and 21 would be as near to a full pitch winding as could be secured for a two-pole motor; if the coil is wound in slots 1 and 19 the coil is chorded two and a half slots and if 1 and 18 it is chorded three and a half slots. Chording reduces the voltage generated in the short-circuited coil and thereby improves commutation, provided the span of the poles is such that the chording does not throw the coil into too strong a field under the pole tip. Chording of the coil is not usually advisable in commutating pole machines, as it requires a much wider pole to produce a commutating field wide enough to act on the short-circuited coil during the entire period of short-circuiting. J.M.H.

659—Heyland Circle Diagram for Induction Motors Below 5 hp Capacity—Should satisfactory results be obtained by using the "circle diagram by test" method

for testing induction motors of capacities below five horse-power?
M.G.D.

The ordinary Heyland Diagram is not satisfactory for small motors, but a modification thereof described by Mr. H. C. Specht in the *Electrical World* for February 25, 1905, is used on small motors only, and should give satisfaction. K.L.H.

660—Effect of Number of Turns in Armature Coil on Characteristics of Motor—What conditions determine whether say, two or three turns per coil shall be used in the design of a direct-current armature, and when should each be used? Is there any difference in the field windings in either case? What effect does the number of turns have on the speed and voltage at the terminals?
J.E.S.

In the design of a direct-current machine, the number of turns used per coil is determined by the number of commutator bars required, the number of armature slots, and the voltage and speed for which the machine is designed. The number of turns in the field coil is always dependent on the line voltage, and not on the armature design. The field coils are sometimes operated in parallel, and sometimes all in series, depending on the voltage for a given number of turns desired. The greater the number of turns per armature coil for a given armature winding, the less the number of commutator bars, and the greater the voltage between commutator bars. This voltage must not exceed a certain maximum, (found by experience), for a given design of machine, size of commutator and thickness and spacing of commutator bars, etc., also the fewer the turns per armature coil, the better the commutation, as a rule, especially in non-commutating pole machines. The design of a given armature must take into consideration the various current, voltage and speed requirements for a given capacity of machine, also the number of armature slots and commutator bars which are to be used, so that it is impossible to give any rule which alone would fix the number of turns per armature coil.
J.M.H.

661—Effect of Accidentally Reversing Primary of Loaded Induction Motor—What would be the reaction in a 300 hp, three-phase, variable speed, 440 volt, 200 amperes, 580 r.p.m. motor if the primary contacts were reversed at full load and full speed? I have noticed in the operation of induction motors with the ordinary controller that there is a flash across the brushes or a punctured winding in case the controller lever accidentally passes the off position due to a weak or broken ratchet spring. C.T.L.

These conditions of operation are covered in No. 493, November, 1910. If full voltage is applied to an induction motor running at approximately synchronous speed in a direction opposite to normal, the machine will still have the characteristics of an induction motor. It will not deliver energy to the line but will draw sufficient energy from the circuit to cover all the losses in the motor, the current being equal to or somewhat above the "locked" current; that is, the current in the secondary circuit would be very high, unless a high resistance is inserted in the secondary circuit (the conditions obtained in the present case). In the present case, while approximately synchronous speed would be obtained at the moment of reversal of the primary circuit, the speed of the motor would drop rapidly. At the moment of reversal the voltage and the frequency of the current in the secondary circuit would be double their normal values. (The secondary frequency is equal to slip × primary frequency). The double value of voltage, and the high secondary current corresponding to such voltage, are the probable causes of puncture and flashing at the brushes in the secondary circuit. R.S.F.

662—Magnet for Testing Armature Windings—Can the alternating-current magnet shown in Fig. 105, article on "Winding of Dynamo-Electric Machines," in the JOURNAL for Dec., 1910, be applied to small induction motor stators in testing for short-circuited coils? How is the magnet designed? In case only one turn of the coil was short-circuited would it not take a magnet of a great number of

turns to induce magnetic flux sufficient to attract even a small piece of iron? D.E.V.P.

Yes, however, a much smaller device would be more convenient. The testing device consists essentially of built up U-shaped punchings with an exciting coil wound upon them. For small armatures, a core of about six sq. in. cross-section would require approximately 120 turns of No. 10 B. & S. wire in the exciting coil for 60 cycles, 110 volts, or 280 turns for 25 cycles, 110 volts. Care should be taken in clamping the punchings together, that a non-magnetic material such as brass be used, otherwise a large amount of the flux will leak through the bolts, etc. It makes little difference whether one or more turns of the coil under test are short-circuited. H.D.B.

663—**Three-Phase Motor Changed to Single-Phase**—What modifications are necessary in the stator winding of a five hp, three-phase, four-pole, 60-cycle, 220-volt induction motor, speed 1 800 r.p.m., 12.8 amperes per terminal, to change it to a single-phase motor, and would the rotor have to be changed? Would it still be run on a 220-volt line; would the poles have to be the same, and would it still have the same horsepower, and r.p.m.? S.M.N.

This motor may be operated on a single-phase circuit without any change in voltage or winding, simply by connecting the two lines to two of its terminals and leaving the third one open. The rotor need not be changed. The single-phase rating will be about three hp and its speed will remain approximately the same, or possibly two or three percent lower. The motor, however, must be started by external means, as it would probably cost more to make it self-starting than the price of a new self-starting motor. H.L.B.

664—**Winding Pitch of Induction Motors**—In the stator winding of a single-phase induction motor, what is meant by a winding pitch of 75 percent? If a single-phase motor has a symmetrical three-phase winding and the following data: No. of slots in stator, 48; stator coils, 48; coils per group, 4; No. of poles, 4; all stator poles connected in multiple; speed of rotor, 1 800 r.p.m., what should be the coil throw? A.L.U.

The percent pitch is the percent of the pole arc spanned by each coil. In a four-pole machine with 48 slots, there are consequently 12 slots or teeth per pole and if the coil then has a throw of 1 and 10 it spans 9 teeth out of 12, or 75 percent. The percent pitch to be used in a machine varies according to its design. This is determined by the designer, as it affects both leakage and induction to a considerable extent. To find what the pitch of the above motor should be inquire of the manufacturer, giving serial number and its complete rating. H.L.B.

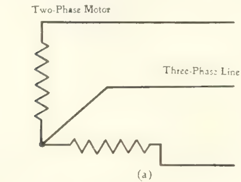
665—**Changing Frequency of Fan Motor**—It is desired to rewind a 12-inch, 8-pole, 125-cycle fan motor for operation on a 60-cycle circuit. Can this be done, and how? W.F.W.

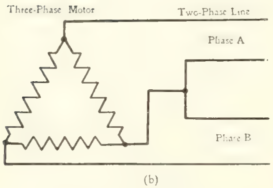
This is covered in a general way by No. 339, December 1909. Four poles should be used to obtain the desired speed. Although it would be most advisable to refer the matter to the manufacturers, the following may possibly be of assistance. Rewind the motor for four poles instead of eight, using the same distribution and connection of the windings as at present, except that five percent more wires per slot should be used in the main and starting windings than at present. The wire sizes should remain the same as at present provided it is possible to find room for them in the winding spaces. This should give a speed of approximately 1 600 r.p.m. on a 60 cycle circuit of the same voltage as at present. H.M.S.

666—**Changing Number of Phases of Induction Motor**—Is it practical to run a two-phase induction motor on a three-phase circuit, connected as shown in Fig. 666 (a) or a three-phase motor on a two-phase circuit as in Fig. 666 (b), assuming that the voltages of the motors correspond to line voltage. Can a two-phase motor be reconnected for three-phase, or vice versa? If so how? In rewinding a two-phase motor for three-phase

or vice versa, can you give me any formulas for finding size of wire, throw of coils and number of turns; the speed and voltage to remain the same in all cases. A.B.

It is possible to operate two-phase motors on three-phase circuits and vice versa in the manner indicated, but, ordinarily it would not be practicable, as the performance, i. e., efficiency, power-factor, etc., becomes extremely poor and, due to greatly





Figs. 666 (a) and (b)

unbalanced currents in the different phases, the motors are apt to overheat. In regard to re-connecting or re-winding, this is usually possible, but as the method of procedure varies considerably with different designs, it would be best to refer to the manufacturer for instructions in each individual case, giving the serial number and full rating of the machines in question. H.L.B.

667—Sections of Armature Coil with Different Numbers of Turns—In winding a direct-current armature what objection, if any, would there be if, to get required speed, one section of a three section coil were wound with a different number of turns than the other two? For example, 29 slots, 87 bars, sections per coil 3, wires per slot 10. This makes one section with one turn and two sections with two turns each. A.W.R.

Armatures have been wound in this manner with satisfactory results. With an armature so wound, satisfactory operation will depend largely upon whether or not the proportions of slot, core and pole are such that satisfactory commutation would be secured if all of the coils were made two-turn. That is, if the induced voltage in the coils short-circuited by the brushes is low enough, the machine will probably operate satisfactorily, though there is a possibility that there may be enough unbalancing of current delivered to the coils by the brushes to cause spotting of the commutator. J.M.H.

668—Currents and Voltages in Auto-Transformer—In a step-down auto-transformer, does that section of the coil between the secondary leads carry more current than the primary section? For example, if 1 000 watts are taken by the primary at 100 volts and 10 amperes, would 100 amperes flow if the secondary voltage is 10 volts. B.L.

Yes, the section of the winding which serves as both primary and secondary carries a current greater than that of the remaining section, and the amount of copper in the secondary section should be correspondingly greater. The total power (voltage × current) in the secondary section must equal the total power in the primary section. Thus, for the above example, with a secondary voltage of ten volts, a total secondary current of 100 amperes and a primary applied voltage of 100 volts, the voltage across the primary section of the winding exclusive of the part which serves also as the secondary, will be 90 volts, and its current ten amperes. The products are seen to be equal. This was covered by No. 303, Sept., 1909. W.M.M.

669—Lightning Arrester Ground For a Three-Wire Direct-Current Lighting System—I have equipped a three-wire, direct-current 2 x 120 volt overhead lighting system with type MP. lightning arresters. The neutral is at several points along the line. The five copper wires of

the system are arranged symmetrically about the axis of the pole in the following way: The grounded neutral is carried on the top of the poles; the + and — street lighting wires 16 inches lower and 16 inches apart in the same horizontal plane and the + and — house lighting distribution wires 16 inches under the street lighting wires. All lamps are branched between the neutral and one of the outers. The neutral, common to street lighting and ordinary house lighting being grounded, is not protected in any other way. The street lighting wires, being in the protective zone of the neutral, have no special protection either. The two lower wires, although also protected by the neutral are equipped with MP. arresters, a certain number of poles carrying two arresters, to the line terminals of which the outers are connected. The ground terminals are both connected to an earth plate which also serves to ground the neutral. Is there any objection to this practice and do you think it is allowable to leave the street lighting wires without arresters? What is the maximum safe distance between the pairs of arresters along a level road with few trees and fewer houses in a country where lightning disturbances are frequent but not severe. P.B.

There will be no objection to a combined ground if the frames of the machines are also connected to it, and a good ground is obtained. It is preferable to have lightning arresters connected to all of the wires and spaced about one thousand feet apart. R.P.J.

670—Ground Detector for Circuit with one line Normally Grounded—A very simple, though not particularly sensitive, ground detector for a two (or three) wire low voltage circuit consists of two lamps connected in series across the outers, the voltage of these lamps to be the same as the difference of potential between the outer leads. The wire which joins the lamps is grounded. Is there a similar device for a system, one of the wires of which is permanently grounded? P. B.

The purpose of a ground detector is to give a warning when the first break in insulation occurs, thereby giving time to repair it, before a second one of opposite polarity may occur and thus cause damage. If the opposite polarity is purposely grounded there is thus no object in indicating a ground on the normally ungrounded wire, as it will manifest itself with sufficient certainty without any ground detector. We do not know of any indicating scheme that can be used for this purpose. P.M.

671—Relation of Current and Voltage in Generator—What is the principle involved in increasing the amperage and decreasing the voltage given out by a dynamo? Can the amperage be increased without raising the voltage correspondingly and vice versa? What is the relation of these quantities to the output? J.L.C.

In the ordinary dynamo the voltage is varied by changing the excitation of the field magnets. The voltage which can be obtained is limited by maximum excitation obtainable with a practicable amount of exciting current, and in the ordinary machine it is rarely possible to obtain more than, perhaps, 10 percent higher than normal voltage. The voltage can be decreased to any extent desired by decreasing the excitation of the field, but as the voltage is lowered the permissible amperage will be limited by sparking at the commutator. As the voltage is lowered and the field weakened, the effect of the armature reaction (due to the current flowing in the armature) is increased so that as the voltage is decreased the current must also be decreased in order that good commutation may be obtained; thus the kw output (the product of volts and amperes divided by 1 000 equals kw) will decrease rapidly with decrease of voltage. The extent to which the ampere output must be reduced as the voltage is reduced depends upon the commutating qualities of the machine concerned. If the machine, however, is not of the ordinary type, but is provided with auxiliary or commutating poles, the current output will be practically independent of the voltage delivered by the generator, and will be limited only by the heat-

ing of the windings and not by sparking at the commutator. In fact, in many generators of the auxiliary pole type, the voltage can be reduced from maximum to zero without decreasing the current output, as the harmful effect of the armature reaction is altogether prevented by the use of the commutating poles. F.I.H.

672—Efficiency of Mercury Arc Rectifier Sets—How does the efficiency of the mercury arc rectifier set vary with the age of its tube? These tubes are guaranteed from 400 to 600 hours and sometimes exceed this guarantee by several thousand hours. Now assuming that an 85 light, 6600 volt, 25 cycle, 6.6 direct-current ampere set had an initial efficiency of 90 percent, what would be the conditions after the tube had been in operation 3 000 hours or five times the maximum guaranteed duration of life? A.W.W.

The efficiency of the bulb does not decrease with increase in life. The bulb has a constant loss of approximately 125 watts at any reasonable load. The loss in the bulb is a very minute proportion of the losses in a complete rectifier outfit. Even if the loss in the bulb doubled toward the end of its life, the efficiency of the rectifier outfit would be little affected. C.E.S.

673 — Starting Characteristics of Wound Secondary Induction Motor—When the starting resistance is removed from a five hp., 60 cycle, three phase, 220 volt, 1 200 r.p.m. induction motor with delta-wound stator, and the secondary winding is short-circuited:— a—Why is the starting torque low except at points? What are the general characteristics while in this condition? As an experiment I put a short-circuiting ring on each end of the rotor winding (sweating on 12 turns of No. 12 copper wire) leaving the original terminals short-circuited. With a portable polyphase wattmeter and an ammeter I found no great difference between the improvised squirrel cage winding and the regular form of squirrel cage machine, except that the starting current was slightly higher and the short-circuiting band ran a little hot at full load. The starting torque was uniform all around the rotor and the losses were about the same. b—If the same rotor winding were connected in Y instead of in delta, what would be the general characteristics? I believe that some manufacturers use this scheme to start induction motors. A.G.W.

a—In a polar wound rotor, the short-circuit currents are constrained to follow certain paths around the rotor; the counter effect of these currents (armature reaction) upon the stator when at standstill depends upon the relative position of the stator and rotor windings; hence the high and low spots in the torque values observed. In the squirrel cage winding the short-circuit currents are not constrained to follow different paths, but may so dispose themselves as to be different in strength at different points on the periphery of the rotor; thus, the torque at standstill is equalized in two positions and these high and low spots in the torque are eliminated. The general characteristics which would be obtained in this case would be, low slip; good efficiency; low starting torque; high starting current. There should be no difference in the results obtained by measurement in the two cases, provided the work is carefully done. b—The general characteristics would be the same as before, viz., smaller current flowing through a greater number of turns in series, giving the same ampere-turns as in the case of the delta connection. The star-delta arrangement for starting is sometimes used for the primary circuit with cage winding, but not in connection with the secondary winding for starting. A.M.D.

674 — Central Station Power for Factory—Cost of Heating—In estimating the cost of central station power for factory drive, how much should be added for factory heat, using low pressure steam? Can the coal consumption be determined by formula or from results of experience? The space, temperature desired, proportion of windows, and the length of the heating season are variable factors. B.P.

This question can be answered only in general. When exhaust steam is used for heat, the cost of heating is ordinarily taken as being a certain proportion of the total cost of private plant operation. This depends upon the following factors:—First, amount of steam required to furnish the power requirements of the factory; second, amount of exhaust steam required to meet the heating requirements of the factory; third, relation between time of day at which the maximum power load occurs, and at which the maximum steam heating load occurs. The power and heating requirements of the factory can be handled in two ways, viz., by generating the power with condensing units and furnishing heating steam from the boilers; or by generating the power from non-condensing units and using the exhaust steam for heating the factory. The choice of methods hinges upon the relative amount of steam required for power, and the amount of steam required for heat. If the power requirements are large so that the installation of non-condensing units would mean that the amount of steam exhausted would be greater than the amount of steam required for heating, then when the cost of this excess exhaust steam is greater than the fixed charges on the cost of a condensing plant over and above the cost of the non-condensing plant, a condensing plant should be installed. When the conditions are reversed, that is, when the demand for low pressure steam is large, a non-condensing plant should be installed. The amount of steam required for heating can be determined within a reasonable degree of accuracy by calculation of the heat losses of the building. If the heating is done by exhaust steam, the value of that steam is sometimes estimated as being the difference between the operating cost, plus fixed charges on a non-condensing plant capable of supplying the total power and heat requirements, and the operating costs and fixed charges on a condensing plant capable of supplying the power requirements alone. It is very rarely the case, however, that existing plants have been installed so that they can be operated under the most economical conditions. It also rarely happens that the maximum power load comes on at a time when the maximum steam demand for heating occurs. In practical operation, therefore, it is necessary at certain times of the day to supply live steam from the boilers for heating, and at other times of the day to exhaust steam from the generating units to the atmosphere. It is practically impossible to formulate any general rule to be followed in all cases; each case must be analyzed separately, as outlined in the foregoing discussion. Under average factory conditions where the demands are diversified and variable, such an analysis becomes quite complicated in detail. See article on "Industrial Engineering by the Central Station," by Mr. John C. Parker, in the JOURNAL for Feb., 1910, pp. 137 and 142. R.D.D.

675—Rotary Converters for 1 200 to 1 500 Volts, 25 Cycles and 60 Cycles—Is it possible to build 25 and 60 cycle, 1 200 and 1 500 volt rotary converters? J.E.S.

Rotary converters for 25 cycles can be built to give 1 200 and 1 500 volts direct-current. Sixty cycle converters have so far not been attempted, on account of the difficulty in getting enough commutator bars with the close brush holder spacing inevitable with 60 cycle converters. F.D.N.

676—Armature Resistance of Rotary Converter—Can the effective armature resistance of a three-ring rotary converter be measured directly with a bridge? For instance, short-circuit rings b and c, so that current enters these rings and flows out of ring a, and then taking the drop across b and a, for instance. Taking a a particular case: The armature resistance on the direct-current end equals 0.01975 ohms for multiple circuit. For a single coil, resistance equals 0.0227 ohms. Resistance on alternating-current end per phase equals 0.0186 ohms. The resistance as hinted at above was not taken. J.D.S.

The effective resistance of a rotary converter cannot be measured

by a bridge. The resistance across rings has a purely mechanical relation to the resistance measured between the bars under adjacent brush holders. The ratio of tfhe resistance measured on the commutator as in a direct-current generator is as follows:—

Direct-current generator ...	1.00
Single-phase converter	1.00
Two-phase converter between rings 1 and 3......	1.00
Three-phase converter, between any two rings......	0.89
Six-phase converter, between rings 1 and 2 . .	0.556

The effective resistance used in calculating the copper loss in the armature is gotten by multiplying the resistance taken across the bars under adjacent brush arms by the constant derived by calculating the ratio of energy loss in the armature coils compared with the same machine operated as a direct-current generator.

The following table gives this ratio for various types of rotary converters:—

D.C.	1-Ph.	2-Ph.	3-Ph.	6-Ph.	12-Ph.
1.00	1.457	0.385	0.585	0.267	0.201

These values show relative current heating, and, therefore, relative energy loss.

The current flowing in the armature conductors of a converter is in effect the difference between the alternating-current input and the direct-current output. A method for the calculation of this current was given in an article by Dr. Steinmetz in the *Electrical World*, for December 17, 1898. C.C.B.

677—Lighting and Power Load on Railway Transmission Circuit— To obtain commercial power and lighting from a three-phase railway transmission line, is it best to use 60 cycles and three-phase—two-phase transformers, or use 25 cycle transmission and change to two-phase, 60 cycles by a motor-generator, using an automatic voltage regulator on the lighting circuits. C.L.G.

(a)—The selection of the frequency for the transmission system will depend upon the relative importance of the railway and other load. If the lighting and power load is of any considerable amount in comparison with the railway load, generation and transmission should be at 60 cycles, and 60 cycle rotary converters used for the railway load. If the lighting and power load is of only minor importance, compared with the railway load, then a frequency of 25 cycles would be best on account of the more rugged operating characteristics of 25 cycle converters. While there has been considerable prejudice among some operators against 60 cycle rotary converters, present designs are entirely reliable and the small difference between the operating characteristics of 25 and 60 cycle converters of modern design does not warrant any material increase in the first cost of the sub-station apparatus. When supplying railway and lighting loads from the same generator some provision for automatic voltage regulation of the lighting feeders will be necessary. This regulation may be accomplished by automatic voltage regulators on the generating units controlled from the voltage of the lighting feeders or by individual feeder regulators installed in the different lighting feeders. The method of regulation that should be selected depends entirely on local conditions. We assume that the reference to two-phase 60 cycle circuits in the question is due to the existence of such circuits. There is, of course, no necessity for transformation from three-phase to two-phase in considering a new system. F.D.N.

678—Rotary Converter vs. Motor-Generator for Railway Work— Compare briefly the rotary converter with the motor-generator for electric railway work, giving points both in favor and against each, including a comparison of cost, efficiency, etc. Let case considered be that of long distance interurban line. C.L.G.

If rotary converters can be used they will be cheaper and most efficient. Under conditions of poor line regulation, however, their operation will probably be unsatisfactory. The motor-generator is less sensitive. In a paper on "Motor-Generators vs. Synchonous Converters, with Special Reference to Operation on Long Dis-

tance Transmission Lines," Trans. A. I. E. E., 1907, Vol. XXVI., p. 303, a comprehensive consideration of this subject is given. This is followed by a discussion covering some 37 pages. From this paper the following is abstracted: 1—Greater realiability may be expected with the rotary converter as there is but one machine instead of two to get out of order. However, in case of trouble on the line, causing interruption of power, the converter has to be re-started and synchronized; the synchronous motor-generator also has to be re-synchronized, unless of the self-starting type; the induction motor, on the other hand, is self-starting. A 25 cycle converter is no more liable to bucking than the direct-current generator of the motor-generator set. Operating conditions in railway work are such that there is greater cause for bucking than in other applications. Sixty cycle converters are more sensitive to such conditions because the brushes are closer together. 2—Ability to adjust the initial voltage is a characteristic possessed by the motor-generator, as the direct-current voltage is absolutely independent of the alternating-current source. The converter suffers its greatest handicap in this regard, unless some special device is provided, because the direct-current voltage is dependent upon the alternating-current source. As regards automatic change of voltage with variation of load there is in general no gain in either type of machine over the other. As regards the effect of variation in incoming line voltage and frequency, the converter has the characteristic of changing the direct-current voltage about in the same percentage as variations on the alternating-current side. The motor-generator, on the other hand, responds, in general, only to change in frequency, the percentage variation in direct-current voltage for a given percent change in the frequency of the alternating-current source being nearly in the ratio of two to one. However, changes in voltage are usually much greater than frequency variations, and accordingly, the converter ultimately does not suffer by comparison. For some applications the rotary converter is absolutely unusable, e. g., where steady voltage is desired for lighting and the alternating-current source undergoes fluctuations of voltage and frequency due to causes other than the direct-current load under consideration. 3—Correction of power-factor of inductive load is obtainable where synchronous machines are connected to the circuit, through increase of field excitation of these machines. As the excitation of the induction motor is inherently beyond the control of the operator it need not be considered in this connection. As regards the converter and synchronous motor, it is primarily desirable that the direct-current voltage remain as constant as possible, independent of the load, and that it shall be adjustable at the will of the operator. Herein, the synchronous machine has a direct advantage in that power-factor correction can be effected without affecting the direct-current voltage. (See Nos. 410 and 420.) 4—The rotary converter has a decided advantage as regards efficiency. It is a case of losses in one machine against losses in two; moreover, in the converter the losses are ordinarily somewhat less than in either of the elements of the motor-generator set. When considering cost of power, this may become a most important factor. 5—As regards cost, the rotary converter has a decided advantage. Again it is one machine against two and the converter cost is not much greater than either element of the motor-generator set. 6—For parallel operation, proper division of the direct-current load must be obtained as well as proper operation on the alternating-current side, so that there will be freedom from hunting. (See Nos. 435, 436 and 442.) In regard to the first of these items there is no question between the two types of machines. In regard to the second item, the induction motor is less liable to trouble, as hunting cannot occur. The synchronous motor and converter are about on a par in this regard. 7—At starting, there should be a minimum draft of current from the line. If starting from the alternating-current end, there should also be ease of synchronizing. As a rule,

good running characteristics from the alternating-current end means poor starting characteristics. The converter has an advantage over the synchronous motor-generator in that only about one-half of the mass is involved. Although the induction motor has better starting characteristics, it also has double the mass of the converter. In case a starting motor is provided, the converter still has this advantage. In regard to synchronizing, the induction motor has a greater advantage in that it is not required. There is little choice between the converter and synchronous motor as regards synchronizing. To summarize:—In 1, 4, and 5 the converter shows a distinct advantage. In 6, all methods are on a par. In 2, 3, and 7 either the synchronous or induction motor set has an advantage over the converter. In 7, the advantage is not marked. In 2 and 3, the disadvantage of the converter largely disappears with the addition of a means of voltage regulation. There are, therefore, but few cases where the rotary converter should not be used in preference to a synchronous or induction motor-generator set. In this same connection note article on "Induction Motor and the Rotary Converter and Their Relation to the Transmission System," in the JOURNAL, Feb., 1905, p. 92. P.M.L.

679—Splicing Belts — Please give formula for splicing together endless leather belts without using rivets. T.L.M.

If a new belt, scarf or bevel the laps; on single belts six inches wide and under making the scarf six inches long; on belts wider than six inches, the lap should be at least equal to the width of the belt. On double belting under 12 inches in width, the lap should be 12 inches long, and for wider belts two inches longer than the width of the belt. Use belt makers' cement, which should be applied hot to both pieces of the lap, and then put the splice under pressure, or hammer with wood or raw hide mallet, or rub down until thoroughly set. Do not use belts for three or four hours after cementing. On old belting the laps should be thoroughly cleaned of all oil, dirt or old cement before applying any cement. A..R.

680—Separating Lightning Arrester Grounds — Two hydro-electric power plants in opposite directions from a sub-station, one with a five mile transmission and the other with a three mile transmission, deliver their power at 11 000 volts. Trouble from lightning has been experienced. Each circuit has five 2 000 volt double-pole lightning arresters in series. A set of Gola type Italian arresters are connected on a short line to an adjoining building containing a 11 000 volt, 600 hp, synchronous motor. Formerly each set of arresters had a ground of its own (about 50 feet apart) but, owing to repeated trouble, the ground wires were all connected together by a No. 4 copper wire. To improve the ground this wire was run back a pole or two where it was connected to an eight inch water main. The ground has only about two feet of soil on top of the rock, which is a soft shaley limestone; water is always found down about four feet. Plates were attached to the ground wires and laid in the water. The hole was then filled with cinders. To further protect the power lines a set of electrolytic arresters is to be installed. Please advise as to whether a separate ground wire should be run into the rocky ground or connection made to the present common ground. Would you advise moving all the other arresters, or not? I have seen a discharge of lightning arc at the horns on the Italian arresters when the three-phase power line switch was open (three single-pole 11 000 volt, quick-break switches). This discharge must have followed back by way of the ground wire to the horns of these arresters. E.W.B.

If the present ground is not over 100 feet distant from the arresters and always wet it should be used also for the new arresters. Continue the old arresters in service also unless their discharge causes disturbance to the power circuit by lowering the voltage or tripping the circuit breakers. R.P.J.

681—Water Rheostat for Maintaining Uniform Load on Hydro-Electric Station — In a hydro-electric power plant situated on a

canal, in which power is generated at 550 volts, three-phase, stepping up to 11 000 volts for transmission, there has been considerable difficulty in regulating the water levels owing to the variable load. When full load is generated, a certain number of stop logs must be in place to maintain the navigation water level. If there is any change in the load, a certain number of stop logs must be raised to maintain the level. In order to overcome this difficulty I propose to use a resistance in the water as a means of maintaining a uniform load on the power-house. One plan was to use iron wire wound in spirals and arranged for three-phase operation, each resistance to take 100 hp, these rheostats being operated from the switchboard by an oil switch with a current controlling coil in the circuit. Four hundred hp would be the maximum power to be absorbed by the resistance. Another suggested plan was to use an adjustable resistance in the water, formed by using three iron pipes, one at each point of an equilateral triangle controlled by raising and lowering into the water. Would you advise me which of these two suggested arrangements is best suited to the purpose. If the latter is approved what distance apart should the pipes be placed and what length and diameter of pipe would be suitable for 550 volts? E.W.B.

Local conditions, such as location of power house, material available and the capital to be invested, would to some extent determine the answer to this question. A rheostat formed of iron pipes or plates arranged to be raised or lowered in the water would be difficult of construction besides being, in most cases, very unsatisfactory. If four wire rheostats, immersed in water, are desired, each to carry approximately 100 hp, we would suggest the following arrangement: For each rack connect in star three sections each formed of approximately 2 000 ft. of No. 10 galvanized iron wire wound in spirals and supported rigidly on iron frames. Care should be taken to have the coils well supported and insulated; also to see that two coils wound in the same direction come side by side in the rack to reduce the inductance as much as possible. C.N.J.

682—Application of Tirrill Voltage Regulator—A Tirrill voltage regulator, type TA, 125, form F3, with alternating-current voltage of 100-125 and exciter voltage of 70-140, is to be connected to a 100 kw, 125 volt compound-wound exciter which is supplying power for cranes and motors, also the exciting current for seven 500 kw alternating-current generators whose alternating-current voltage is to be kept constant by the regulator. Will this regulator keep the alternating-current voltage constant and operate satisfactorily? W.S.B.

A Tirrill regulator of the above type used in connection with a 100 kw, 125 volt exciter, should give perfectly satisfactory operation on the seven 500 kw alternating-current generators, if properly connected in accordance with instructions. The trouble experienced in the plant in question, if any, will come from the operation of the cranes and motors from the exciter, as the exciter voltage will vary over a broad range and will no doubt give poor results on the motors and cranes connected to the exciter circuit. If trouble is experienced, another source of direct-current for the cranes and motors should be provided, leaving the exciter completely under the control of the regulator for the single purpose of regulating the alternating-current voltage. A.A.T.

683—Angle Irons Used as Trolley Wires on Crane—On our three-ton electric crane we have considerable trouble in keeping the trolley wires on their supports, due to the length of the spans and vibration. There are seven trolley wires in all. Would one-and-one-half by two-inch angle irons be a satisfactory substitute for the trolley wires, and will an iron collector shoe two and one-half inches long, making contact on the edge of the angle iron, be sufficient for 150 amperes? W.S.D.

Many cranes have been furnished with this construction, and so far

as we know they have given excellent satisfaction. For the current mentioned in the question we would recommend a $1\frac{3}{4}$ in. by $1\frac{3}{4}$ in. by $\frac{1}{4}$ in. angle iron with a shoe 12 inches long running on the flat side of the angle.
C.L.T.

684—Charging Storage Battery with Electrolytic Rectifier—A 30 volt, 40 ampere - hour storage battery that is to be used for operating about 40 secondary clocks, a small private telephone line, and a fire alarm system (closed circuit), is to be charged from a 110 volt, alternating-current line through an "American" rectifier. As there is only one set of batteries, can the clocks and other apparatus be operated at the same time that the battery is charging, or is it necessary to stop the clock, etc., while the battery is under charge? Is it necessary to have an adjustable resistance between the rectifier and battery? What other switches, etc., are necessary for charging and discharging? J.S.S.

It should not be necessary to disconnected the circuits mentioned while charging the battery by means of the electrolytic rectifier. There may be a hum in the telephone receiver while the battery is charging, but if the frequency of the alternating supply circuit is 60 cycle or lower this hum will not interfere with the operation of the telephone unless the alternating voltage wave is serrated with high harmonics. To reduce the effect of pulsating charging current to a minimum in the service lines, the direct-current circuit from the rectifier should be connected to the battery terminals instead of to bus-bars or wires connecting the service lines with the battery. It would be advisable to use an adjustable resistance and switch between the rectifier and battery. A switch to disconnect all of the rectifier circuit from the alternating-current service should also be installed, and should be used to stop the charge. L.W.C.

585—Unbalanced Motor-Load on Three-Phase Transformer Bank—Two three-phase motors of seven and five hp, respectively, are connected on a 220 volt, three-phase, three-wire circuit receiving power from three transformers. A 220 volt single-phase motor of two hp was connected across one outside and the middle wire of the three-phase circuit, but it seemed to interfere with the operation of the other motors, as a fuse blew in the middle phase of the seven hp motor. How could the single-phase motor affect the other motors?
J. S. S.

The question is not stated with sufficient clearness and detail to make a definite answer possible. It is known that a wound induction motor when operated from a balanced supply circuit will have equal currents in all leads and when operated from an unbalanced circuit will have unequal currents. If it is assumed that the polyphase motors are operated from small transformers or transformers having poor regulation, the circuits may be unbalanced by the starting of the single-phase motor. This unbalancing of the circuits will result in unequal currents in the motor leads and may cause the fuse to blow in the lead having the greatest current. R. S. F.

686—Reactance Used with Turbo-Generators—Is it usual practice to install reactance in connection with large 25 cycle turbo-generators? The writer has run across various installations where reactance has been used, but finds it is only in few and scattered installations. Are there other advantages gained by the use of reactance than the fact that it limits the amount of current that the machine can deliver under absolute short-circuit conditions. F.B.

Reactance coils for turbo-generators have been used only in a few cases where the size of the units or other conditions made short-circuits unusually frequent or severe. For example, they have been used with the turbo-generators in the Cos Cob Station of the N. Y., N. H. & H. Ry. Co., on account of the severity and frequency of short-circuits on the 11 000 volt grounded railway line; on the generators for the Com-

monwealth Edison Company of Chicago, and on the United Electric Light & Power Co. of St. Louis on account of the large size of the generators and large aggregate capacity of the station. There is no advantage to be gained from their installation except the reduced current that will flow during the first few alternations after a short-circuit, and they should only be necessary to protect the generator under these conditions in extreme cases as noted above. F.D.N.

687 — Power-Factor Correction — We have a 75 hp, 2 000 volt, three-phase, 60 cycle induction motor that is running ten hours daily. It lowers the power-factor of our 250 k.v.a. installation to about 45 percent. What capacity of synchronous condenser would be necessary to raise the power-factor to 80 percent. Please explain calculations. A.R.G.

Assuming that the 250 k.v.a. referred to is the actual k.v.a. load of the installation, use the curve of Fig. 3 of article on "Power-Factor Correction", in the JOURNAL for October, 1911, by exterpolating a curve corresponding to 45 percent power-factor. First find the kw load, which equals k.v.a. × power-factor, (as kw remains constant and k.v.a. varies). The wattless component required will be found to be about 105 percent of the kw load whose power-factor it is desired to raise; that is, the kw corresponding to 250 k.v.a. at 45 percent power-factor, or 112.5, ($250 \times 0.45 = 112.5$). Then $112.5 \times 105 = 113$ k.v.a. which equals the capacity of synchronous condenser required to raise the power-factor to 80 percent. If the k.v.a. load were constant and the total kw were varied to suit the correction desired, Fig. 4 would apply. N.S.

688—Rewinding Fan Motor—After rewinding a 104 volt, 60 cycle, four-pole, Tuerk ceiling fan motor the rotor gets extremely hot. New coils were made of same size wire and same number of turns as the old coils. Please explain what causes the rotor to heat. B.E.T.

If the motor was properly rewound and connected to duplicate the original winding the rotor will get no hotter than before, provided the line voltage and the frequency on which it is operated correspond to those for which the motor was designed. It is probably not appreciated that the rotor operates normally at a rather high temperature. An alternating-current fan motor which, on the outside shows only a very moderate temperature when running, will commonly have a rotor which operates at a temperature such that it would be too hot to touch with comfort. Thus, the conditions observed may represent only normal operation of the motor. H.M.S.

689—Oil Type Direct-Current Switches—Please explain the difference between the action of direct current and alternating current on oil, when used in conjunction with switches. The leading switch manufacturers state that oil should on no account be used for direct-current work, but I do not see why this is so, and should like you to give a detailed explanation. J.K.

The difference in the action of direct current and alternating current when broken in oil is wholly due to the fact that alternating current passes through zero once every cycle and the oil in displacing the arc gases, prevents the arc from reëstablishing between the contacts when they have been separated a distance in the oil sufficient to prevent puncture of the oil due to the particular line voltage. This, of course, is a relatively short distance for commercial voltages. With direct current there is no zero point, and if the gas generated by the arc is sufficient to reach the surface of the oil while an arc persists an explosion will result. It would be necessary to have a length of break in oil practically the same as in air for direct current and therefore no advantages result. J.M.M.

CONTRIBUTORS TO THE JOURNAL FOR 1911

Contributors for whom biographical sketches have already appeared in December issues of previous years are indicated by a (*).

A. G. AHRENS, (Rutgers College, '06), before graduation had spent six months in shops of Singer Manufacturing Company; apprenticeship course, 1906 to 1908, Electric Company; 1908 to date, industrial and power sales department of the Electric Company at East Pittsburg.

R. H. ARNOLD, (Purdue Univ., '05); spent six years with Electric Company in the research division of the engineering department—three years on transformer insulation work and three years on research work dealing with the properties and applications of materials; since May, 1911, has been with the Ohio Brass Company in capacity of manufacturing engineer.

*L. M. ASPINWALL, engineer on locomotive equipment, railway division, engineering department, Electric Company.

*C. B. AUEL, assistant manager of work, Electric Company.

*C. W. BAKER, meter and transformer engineer, engineering department, Canadian Westinghouse Company, Ltd., Hamilton, Ontario, Canada.

MEIGS W. BARTMESS, (Oregon Agricultural College '04, Purdue Univ., '06), entered the apprenticeship course of the Electric Company in August, 1906; upon completing the course, he took up his present work in the industrial division of the engineering department.

V. L. BOARD, (Univ. of Missouri, '10), telephone construction work for various telephone companies in Missouri, 1903-1905; telephone switchboard installer, Western Electric Company, 1907; on construction work, Telluride Power Company, summer of 1909; engineering department, Denver Gas & Electric Light Company, 1910 to date.

B. B. BRACKETT, (Syracuse Univ., '90-'93; Johns Hopkins Univ., '97); instructor in Dickinson Seminary, Williamsport, Pa., from 1890-1892; Adelphi Academy, Brooklyn, N. Y., 1892-1893; Johns Hopkins University, 1894-1897; Union College, 1897-1898; Eastern High School, Washington, D. C., 1898-1900; Rutgers College, 1901-1903; professor of physics and electrical engineering, 1903-1908, and professor of electrical engineering, 1908-1909; inspector of torpedo cable for United States Army, 1898; electrical engineer for Rowland Telegraphic Company, Baltimore, Md., 1900-1901; since 1909, present position, professor of electrical engineering, South Dakota College of Agriculture and Mechanic Arts.

L. B. BREED, (Mass. Inst. of Technology, '96), apprenticeship course, Electric Company, 1897-1900; testing department, 1900-1901; erecting department, Boston office, 1901-1902; assistant foreman of testing department, 1902-1903; general foreman of testing department, 1903-1905; engineer in industrial and power sales department, 1905-1910; general engineering department, 1910-1911.

*GRAHAM BRIGHT, locomotive section, railway division, engineering department, Electric Company.

*HAROLD W. BROWN, switchboard division, engineering department, Electric Company.

*D. E. CARPENTER, industrial and power sales department, Electric Company.

*C. E. CLEWELL, lighting division, detail and supply sales department, Electric Company.

C. O. COLLETT, (Technische Hochschule zu Hannover, '05); before graduation connected with Koerting Brothers on erection work in South Germany; fourteen months on engineering apprenticeship course, Electric Company; instructor in electrical engineering at University of Missouri, 1906-7; after this for fourteen month mechanical engineer with the railway construction department of the Electric Company; since January, 1909, engaged in railway project work, engineering department, Electric Company.

*C. R. DOOLEY, president, Casino Technical Night School; secretary, educational committee, Electric Company.

*C. W. DRAKE, commercial engineer, industrial and power sales department, Electric Company.

*EDWIN D. DREYFUS, commercial engineer, The Westinghouse Machine Company.

S. W. DUDLEY, (Sheffield Scien-

tific School, Yale Univ., '00); connected with the Sheffield Scientific School as assistant and instructor in mathematics and mechanical engineering to 1905; entered employ of Westinghouse Air Brake Company, general Engineering and test department work, 1905 to 1906; special inspector at New York City office, 1906-1907; chief of publicity department, 1907-1908; assistant mechanical engineer, 1908-1910; since 1910, assistant chief engineer of operation.

H. B. Dwight, (McGill Univ., '09), graduating with the British Association Exhibition and Medal; before graduation, a short time with the test department of the Canadian Westinghouse Company, and with the engineering department of Allis-Chalmers-Bullock; since graduation, engineer on direct-current design, Canadian Westinghouse Company.

*G. M. Eaton, mechanical engineer, railway division, engineering department, Electric Company.

H. R. Edgecomb, previous to employment with the Electric Company, served as draftsman with Kidder Press Manufacturing Company, Boston, Mass.; instructor in mechanical drawing and mathematics at Berea College, Berea, Ky.; superintendent, Newport Station of New England Electric Vehicle & Transportation Company and superintendent of American Roller Bearing Company, Boston, Mass. Since his connection with the Electric Company, Mr. Edgecomb spent three and one-half years as draftsman on railway motor work; three years as foreman of generating and motor drawing office, and two and one-half years to date as engineer in research division, engineering department.

E. L. Elliott (Cornell Univ., '87); for seven years after graduation was engaged in teaching science, five years of which was spent in the Central High School, Pittsburg; he then became associated with the George A. Macbeth Company, as a lighting specialist, in connection with the Holophane globe patents of which that company had secured the rights for manufacture. Later he was general superintendent of the Holophane Glass Company, of New York City, for five years, during which time he developed the practical manufacture of Holophane glassware. Mr. Elliott later organized the Illuminating Engineering Company, but soon disposed of his interests to accept the management of the Brilliant Electric Company, Cleveland, Ohio, which position he held for about two years. He organized the Illuminating Engineering Publishing Company, and started the publication of *The Illuminating Engineer,* of which he is the editor.

*B. F. Fisher, Jr., commercial engineer, Westinghouse Lamp Company, Bloomfield, N. J.

W. B. Flanders, (Cornell Univ., '02), since graduation, has been connected with the turbine engineering department of the Westinghouse Machine Company at East Pittsburg.

*S. A. Fletcher, central station division, industrial and power sales department, Electric Company.

C. Fortescue, (Queens Univ., '98), engineer in transformer division, engineering department, Electric Company, 1901 to date.

J. W. Fox, obtained his education in England, and, after completing an engineer's apprenticeship, came to this country to continue textile manufacturing work. For twenty years he followed experimental work as master mechanic and chief engineer in various cotton mills and allied industries; now textile sales engineer, Charlotte office, Electric Company.

W. W. Freeman, past president, National Electric Light Association.

J. W. Fraser, (McGill Univ., Montreal, Canada, '99 and '01), during his post-graduate course at McGill University, acted as assistant in physics the first year and assistant in electrical engineering the second year; entered the apprenticeship course of the Electric Company and was later transferred to the erecting department; shortly afterwards accepted a position with the Shawinigan Water & Power Company, Montreal; was engineer in charge of construction in connection with the building of a 50 000 volt transmission line. While with this company, he also made an investigation of the use of telephone lines carried on the poles of high-tension transmission circuits; in the autumn of 1905, he returned to the Electric Company as constructing engineer, later being sent South to take charge of power plants and large motor installations, principally in textile mills. About

this time the Southern Power Company was being organized to take over the Catawba Power Company and in view of his experience, Mr. Fraser was selected as assistant chief engineer of the company, in charge of all electrical design and construction, in which position he has since been identified with the purchasing of all apparatus and construction material for this system.

G. W. Hamilton, indentured apprentice with Neilson & Company, now the North British Locomotive Works, Glasgow, Scotland, from 1887 to 1892; mining engineer Consolidated Coal Company, of St. Louis, from 1892 to 1901; Baldwin Locomotive Works, Philadelphia, Pa., as mining engineer for Baldwin-Westinghouse Companies, 1901-1908; Goodman Manufacturing Company, as engineer and salesman, 1908-1909; Electric Company, as salesman and engineer, Chicago office, 1909-1911; at present at East Pittsburg, Pa., as general engineer, on mining work.

H. K. Hardcastle, (Johns Hopkins Univ., '09), engineering apprentice, Electric Company; engineering department, railway division; engineer on railway construction, erecting department.

C. O. Harrington, Jr., Engineer of materials, Union Switch & Signal Company, Swissvale, Pa.

L. S. Haskin, (Cornell Univ., '02; McGill Univ., '03); after graduation became associated with the erection department of the Buffalo office, Electric Company; two years in charge of lighting plant, Northeast, Pa.; erection department, Cleveland district office, Electric Company; five months in works of the Electric Company at East Pittsburg in connection with the equipment of the Spokane & Inland and the New Haven locomotives; in August, 1906, with the Spokane district office of the Electric Company, associated with the erection department on railway equipment for the Spokane & Inland Railway Company; for sixteen months was detailed to erection work at Aberdeen, Washington, in connection with the construction of a railway and lighting power house; later connected with the Seattle district office as tester and engineer, and in February, 1909, stationed at Spokane in the sales department of the Electric Company.

*S. Q. Hayes, general engineer, engineering department, Electric Company.

*J. M. Hipple, formerly engineer on direct-current motor design, industrial division, engineering department, Electric Company; at present engineer in charge of industrial division.

*J. S. Hobson, assistant general manager, Union Switch & Signal Company, Swissvale, Pa.

*Francis Hodgkinson, engineer, turbine department, The Westinghouse Machine Company.

H. H. Holding, (Rose Polytechnic, '89), after a brief student's course at the Lynn works of the Thomson-Houston Electric Company, was assigned to the engineering or erection department, first at Boston, and later at Cleveland, Ohio, where he had charge of erection work for the Cleveland office of the General Electric Company. In 1894, he became engineer in charge of the electric department during the construction of the Lorain Steel Works. His first work with the steel company was the installation of ten miles of electric railway operating between Elyria and Lorain, one of the first high speed lines in the country. In 1897 he opened an office at Cleveland, Ohio, engaging in steam and electrical engineering, paying special attention to the application of motor drive. In 1909 he entered the employ of the Electric Company, being assigned to the industrial and power sales department of the New York district office.

F. Hymans, studied at the University of Delft (Holland); continued his technical training at the University of Stuttgart, Germany; was employed for two years each at the Maschinenfabrik Esslinger and Maschinenfabrik R. Stahl, Wurttemberg, Germany, in the former for the design of boilers and steam engines, and in the latter for the design of electric cranes, elevators and the like; came to America in 1902 and has since been in the employ of the engineering department of the Otis Elevator Company, and is at present connected with the Pittsburg office of the company as engineer.

*R. P. JACKSON, engineer in charge of protective apparatus and mercury rectifiers, detail and supply division, engineering department, Electric Co.

*J. HENRY KLINCK, commercial engineer, industrial and power sales department, Electric Company.

G. B. KIRKER, railway and lighting sales department, Los Angeles district office, Electric Company.

*B. G. LAMME, chief engineer, Electric Company.

A. C. LASHER, (Iowa State College, '03), with the Electric Company for five years after graduation in the following connections: Apprenticeship course, fifteen months; transformer division, engineering department, three years; erecting department, Chicago and Atlanta district offices, eighteen months; since August, 1908, chief electrician, Central of Georgia Railway Company, Macon, Ga.

CHARLES A. LAUFFER, received the degrees of A.B. and A.M. from Franklin and Marshall College, Lancaster, Pa., and M.D. from University of Pennsylvania. Served as resident physician in the Chester Hospital, Chester, Pa., and also in the Philadelphia General Hospital; spent fourteen months in the clinics of Vienna and Berlin, and in foreign travel; then located in Wilkinsburg, a suburb of Pittsburg, where he is still engaged in the practice of his profession; fourth year as medical director of the relief department of the Electric Company.

C. S. LAWSON, (Mass. Inst. of Tech., '02), served apprenticeship with General Electric Company, after which spent one year with operating companies in South; for past six years, transformer division, engineering department, Electric Co.
neering department, Electric Co.

EDWIN E. LEHR, (Purdue Univ., '01), with Electric Company since graduation, on apprenticeship course, transformer division, detail and supply division and industrial division, engineering department; for about two years engineer in charge of regulator design.

BERNARD LESTER, (Haverford College), was engaged in general engineering work in Philadelphia, 1903-1904; connected with Jones & Laughlin Steel Company, 1904-1905, in general engineering and testing work and had charge of testing material of construction in new open hearth furnaces; 1905 to date with Electric Company in sales engineering work in connection with small motors and small motor applications and electric vehicle equipments; present position, head of small motor division of the industrial and power department.

*P. M. LINCOLN, general engineer, Electric Company.

*H. E. LONGWELL, consulting engineer, The Westinghouse Machine Company.

*W. M. MCCONAHEY, engineer in charge, transformer division, engigineering department, Electric Co.

HAROLD MCCREADY, engineer-in-charge, electrical department, Union Switch & Signal Company, Swissvale, Pa.

*D. C. MCKEEHAN, with Tomboy Gold Mines Company, Smuggler, Colorado.

*PAUL MACGAHAN, meter engineer, detail and supply division, engineering department, Electric Co.

L. A. MAGRAW, (Worcester Poly. Inst., '05), was with the Crocker-Wheeler Company from 1905 to 1907 in charge of alternating-current test; entered the employ of the Electric Company in 1907, first at Philadelphia in the erecting department, and in 1909 with the engineering department at East Pittsburgh; from 1909 to 1911, he served as an active field engineer in connection with several large power transmission companies in the East and South; in November, 1911, he accepted the position of chief engineer, Central Georgia Power Company.

J. FRANKLIN MEYER, (Franklin & Marshall College, '94 and '97; Johns Hopkins Univ., and University of Penna., Ph.D., 1904); instructor and assistant professor of physics, University of Pennsylvania, 1902-1907; professor of physics, Pennsylvania State College, 1907-1909; physical engineer, Westinghouse Lamp Company, 1907 to date.

GRAY E. MILLER, (Penna. State College, '08); in charge of mechanical drawing and assistant in mathematics, Steelton High School, 1908-1909; entered apprenticeship course of Electric Company, 1906; industrial division, engineering department, 1909 to date.

*H. N. Muller, superintendent of distribution, Allegheny County Light Company, Pittsburgh, Pa.

W. S. Murray, (Lehigh Univ., '95), for three years on apprenticeship course, Electric Company; then district engineering work, Boston district office; continued in this and sales work until 1901, when he resigned to take up consulting engineering with headquarters at Boston; experience gained during this time aroused his interest in power transmission problems, and in single-phase electric railway development; he foresaw the possibilities of electric trunk line operation based on the use of alternating current; early in 1905, when the New York, New Haven & Hartford Railroad was perfecting plans for the electric operation of their trains through the Park Avenue tunnel and the subsequent extension of the zone of electrification, Mr. Murray was appointed as their electrical engineer.

*F. D. Newbury, engineer in charge, power division, engineering department, Electric Company.

S. L. Nicholson, began his electrical work in the factory of the Novelty Electric Works, in Philadelphia, and in the following year became associated with the Chadborne-Hazelton Company, of Philadelphia, who were at that time representatives for the Sprague Electric Railway & Motor Company. An affiliated interest of the Chadborne-Hazelton Company was formed, known as the Equitable Electric Railway Construction Company, and Mr. Nicholson was made superintendent of construction. The Chadborne-Hazelton Company became the representatives of the Wenstrom Dynamo & Motor Company, of Baltimore, and Mr. Nicholson was placed in charge of the dynamo and motor sales. His services were terminated with these interests after he had spent considerable time in operating work at Bristol, Tenn., for the Bristol Belt Line Railway Company. He then became a representative of the Short Electric Railway Company at Philadelphia and afterwards was transferred to their headquarters at Cleveland, as assistant superintendent of construction. In 1893, he accepted a position with the Technique Electrical Works at Philadelphia, manufacturers of switchboard apparatus. Later he was made manager of the electric railway supply department of James Boyd & Brother, and following this he became connected with the Cutter Electric & Manufacturing Company. From this position he went to the C. & C. Electric Company, where he had charge of the dynamo and motor sales in New York City. Mr. Nicholson became connected with the Electric Company in 1898, when he took charge of the sales of motors and engine-type generators in the New York City territory. He was later placed in charge of the city sales work of the New York office. Subsequently Mr. Nicholson was made New York manager of the newly established industrial department; up to this time electric motors were but little used in ordinary industries and were almost a novelty in the machine shop. He made a personal engineering study of several industries, determining their conditions of operation and the changes which might be brought about by electric drive, and the various direct and indirect advantages which would result; in this connection he did a considerable amount of pioneer work. When the sales activity of the Company was segregated into the industrial and power sales, the railway and lighting sales, and the detail and supply sales departments, Mr. Nicholson was appointed manager of the first branch with headquarters at New York and Pittsburg. His experience as a consulting engineer was, of course, of assistance to him in the organization of this new department, and he succeeded in building up a large business by the employment of engineering specialists having expert knowledge of the application of electricity to various important industries. Mr. Nicholson was appointed to his present position as sales manager of the Electric Company in June, 1909.

R. D. Nye, (Ohio State Univ., '03), took the apprenticeship course of the Electric Company, and then entered the sales department and is at present located at the Cleveland district office.

*L. A. Osborne, vice president, Electric Company.

*W. H. Patterson, industrial and power sales department, Electric Co.

W. F. Patton, Jr., (Cornell, '06), with the Electric Company as apprentice, and in the erecting and sales departments; now connected with the industrial and power sales department at East Pittsburg.

*J. S. Peck, consulting engineer, British Westinghouse Electric & Manufacturing Company.

*T. S. Perkins, engineer in charge, detail and supply division, engineering department, Electric Company.

Luther P. Perry, (Tufts College, '05), after twenty months' apprenticeship at the Stanley-G. I. Electric Manufacturing Company, became superintendent of the hydro-electric plant, and then supervised a street railway extension for the Fries Manufacturing & Power Company, North Carolina; originated and promoted the Arcoil, an electrical device in general use with moving picture machines; power engineer for the Connecticut Company at Waterbury, Conn.; since 1909, commercial power engineer, Narraganset Electric Lighting Company, Providence, R. I.

J. F. Peters, entered the employment of the Electric Company, April, 1905; in February, 1906, became connected with the transformer division, engineering department, on design of large power transformers, which position he now holds.

*A. G. Popcke, industrial and power sales department, Electric Co.

*H. G. Prout, vice president and general manager, Union Switch & Signal Company, Swissvale, Pa.

*K. C. Randall, engineer in charge, switchboard division, engineering department, Electric Co.

*Allen E. Ransom, in charge of industrial and power sales department, Seattle office, Electric Co.

Clarence Renshaw, engineer, control section, railway division, engineering department, Electric Co.

A. E. Rickards, formerly in sales work with the Pittsburgh district office of the Electric Company; at present, general manager, Industrial Engineering Company, Pittsburg.

Charles R. Riker, (Mt. Union College, A.B., '04; A. M., '06; Armour Inst. of Tech., B.S. in E.E., '06); Denver Gas & Electric Company, July, 1906, to February, 1907; Union Gas & Electric Company, Cincinnati, February, 1907, to February, 1910; assistant editor, The Electric Journal, February, 1910, to date.

*L. G. Riley, engineer, control section of the railway division, engineering department, Electric Co.

*C. H. Sanderson, switchboard division, engineering department, Electric Company.

George P. Scholl, consulting engineer, Westinghouse Lamp Company, Bloomfield, N. J.

*Chas. F. Scott, consulting engineer, Electric Company; professor of electrical engineering, Sheffield Scientific School, Yale University.

*F. H. Shepard, special representative, Electric Company.

*H. D. Shute, acting vice president, Electric Company.

E. T. Sill, (Ohio State Univ., '04), took apprenticeship course at the Electric Company; from July, 1906, to date, erecting department, Pittsburg office, Electric Company.

*C. E. Skinner, engineer in charge, research division, engineering department, Electric Company.

H. W. Smith, (Univ. of Adelaide, South Australia, '06; Cornell Univ., '98), won traveling scholarship and came to United States in 1907; with Wagner Electric & Manufacturing Company nine months, in test work and later transformer engineer; two years on apprenticeship course of the Electric Company; now with the Milwaukee office.

J. L. Smith, motor testing department, Wagner Electric Company; apprenticeship course and erection department, Electric Company; engineer for St. Joseph (Mo.) Railway, Light, Heat & Power Company; at present with sales department, Carnegie Steel Company.

E. H. Sniffin, sales manager, The Westinghouse Machine Company.

*H C. Specht, industrial division, engineering department, Electric Co.

E. R. Spencer, (Case School of Applied Science, '04); summer of 1901, machinist department, Union Steel Screw Company; drafting department, Isthmian Canal Commission, Washington, D. C.; summers, 1902-1903, electrical department, Brown Hoisting Machinery Company; 1904-1905, apprenticeship department, Electric Company; 1905, detail and supply division, engineering department, and last six months of 1906, editorial division of publication department, Electric Com-

pany; January, 1907, to date, assistant editor, THE ELECTRIC JOURNAL.

THOMAS SPOONER, (Bates College, '05; Mass. Inst. of Tech., '09), for one year with Stone & Webster; one year with the Odell Manufacturing Company, of Groveton, N. H., in paper mill design; with the Electric Company in 1909 as an apprentice; no wwith research division, engineering department.

NICHOLAS STAHL, (Princeton Univ., '97), at Princeton for one year after graduation as fellow in physics; in 1908 received degree of A.M. from Princeton, and later appointed in charge of science department, Lawrenceville School, a preparatory school for Princeton and other colleges; during this time made study of Röntgen waves and radiography; pursued course at Harvard and in 1905 took course at Technische Hochschule, Charlottenberg, Germany; in 1906-1907, studied electrical engineering at Princeton, giving particular attention to oscillographic work and receiving post-graduate degree of E.E.; since 1907 with Electric Company, as engineering apprentice, construction and test work on Spokane & Inland and New Haven locomotives; entered railway sales department as corresponding engineer; during same period instructor in the Carnegie Technical Schools, Pittsburg; at present, commercial engineer, railway and lighting sales, Electric Company, head of general contract division.

*N. W. STORER, engineer in charge, railway division, engineering department, Electric Company.

J. E. SWEENEY, entered employ of Electric Company during 1905 as a special apprentice; was connected with the department of electricity of the Jamestown Exposition Company, at Norfolk, Virginia, during 1906 and 1907; returned to Electric Company in 1908 to take up work in the office of the assistant to the first vice president, recently assigned to the industrial and power department.

*W. A. THOMAS, commercial engineer, in charge of mine division of industrial and power sales department, Electric Company.

FRANK THORNTON, JR., (Univ. of Missouri, '08), one year at Technische Hochschule, Charlottenberg, Germany; one year in apprenticeship course, Electric Company; at present, connected with heating appliance section, engineering department, Electric Company.

F. E. TOWN, (Tufts College, '98), after graduation was connected with the meter and instrument department of the General Electric Company; during 1899 and part of 1900, he was superintendent of meter departments of the Potomac Electric Power Company and the United States Electric Lighting Company, respectively, Washington, D. C. From June, 1900, to July, 1902, he held the position of electrical engineer in the supervising architect's office, United States Treasury Department. From July 1st, 1902, to date he has been with the Otis Elevator Company as assistant superintendent of construction, assistant to general sales manager, and manager of the Pittsburg office, which last position he still holds.

W. V. TURNER, chief engineer, Westinghouse Air Brake Company.

M. C. TURPIN, (Alabama Poly. Inst., '01), after post-graduate course at Cornell University, took testing course, Schenectady works of General Electric Company; with Philadelphia office engaged in construction and trouble work; resigned (1907) to become manager Auburn (N. Y.) Light, Heat & Power Co.; employed by Public Service Commission, New York City, on appraisal work of street railways; resigned (1909) to accept position with Electric Co., in the department of publicity.

*K. E. VAN KURAN, formerly in charge of the switchboard division of the detail and supply sales department of the Electric Company at East Pittsburg; now, assistant manager, Los Angeles district office.

H. C. WALTER, (Worcester Poly. Institute, '00), spent a year and a half in the testing department of the General Electric Company at Schenectady; instructor in electrical engineering at the N. C. College of Agri. and Mech. Arts, Purdue Univ., and Worcester Poly. Inst., successively; professor of physics and electrical engineering at N. C. College of Agri. and Mech. Arts, 1908-1909; in the industrial division, engineering department, Electric Co., since June, 1909.

*ALBERT WALTON, industrial and power department, Boston district office, Electric Company.

J. W. WELSH, (Wittenberg College, '00; Harvard, '01; Mass. Inst. of Tech., '03), steel mill work, National Tube Company, Wheeling, W. Va., 1904; engineering apprentice, Electric Company, 1905; construction and sales department, Electric Company, 1906; assistant electrician, Pittsburgh Railways Company, 1906-1910, and electrical engineer, 1910 to date.

*GEORGE WESTINGHOUSE, president of various Westinghouse interests.

*BRENT WILEY, commercial engineer of the industrial and power burg office, Electric Company.

*W. B. WILKINSON, manager, central station motor department, Pittsburg district office, Electric Company.

*LEONARD WORK, erecting department, Philadelphia district office.

*C. I. YOUNG, commercial training department, Electric Company.

CONTRIBUTORS TO THE JOURNAL QUESTION BOX—1911

A special feature of The Journal Question Box is the authoritative character of the replies. The inquiries cover such a range of subjects that no ordinary editorial staff could hope to give as comprehensive answers as are obtainable through the assistance of specialists along various lines. Moreover, before publication, the answers receives the supervisory attention of engineers who are in a position to review them in a broad and experienced way.

The following list of contributors to the Question Box, which gives both the names and respective positions of those who have furnished information regarding inquiries during 1911, is of particular interest as an indication of the qualifications of those who have been instrumental in making this department one of the valuable assets to be acquired through a subscription to the JOURNAL. The majority of the contributors are associated with the Electric Company at East Pittsburg.

J. L. ADAMS, JR., detail and supply division, engineering department.

R. W. ATKINSON, assistant to chief engineer, Standard Underground Cable Company.

C. B. AUEL, assist. manager of works.

JENS BACHE-WIIG, formerly, engineering dept.; professor of electrical engineering, Technical University of Trondhjem, Norway.

H. L. BARNHOLD, industrial division, engineering department.

M. W. BARTMESS, industrial division, engineering department.

A. P. BENDER, transformer division, engineering department.

W. J. BOTHWELL, dynamo test.

D. A. BOWEN, detail and supply division, engineering department.

H. D. BRALEY, transformer division, engineering department.

GRAHAM BRIGHT, railway division, engineering department.

C. C. BRINTON, dynamo test.

HAROLD W. BROWN, switchboard division, engineering department.

A. BRUNT, industrial division, engineering department.

L. W. CHUBB, research division, engineering department.

F. CONRAD, general engineer, detail and supply division, engineering department.

A. W. COPLEY, detail and supply division, engineering department.

L. DELAVAL, industrial division, engineering department.

R. D. DEWOLF, assistant mechanical engineer, Rochester Railway & Light Company, Rochester, N. Y.

W. A. DICK, power division, engineering department.

E. D. DREYFUS, commercial engineering, The Westinghouse Machine Company.

A. M. DUDLEY, industrial division, engineering department.

G. M. EATON, mechanical engineer, railway division, engineering department.

R. S. Feicht, manager of engineering, Electric Company.
L. H. Flanders, engineer, Electric Storage Battery Company, Philadelphia, Pa.
C. Fortescue, transformer division, engineering department.
F. C. Hanker, general engineer, engineering department.
K. L. Hansen, industrial division, engineering department.
S. Q. Hayes, general engineer, engineering department.
R. E. Hellmund, railway division, engineering department.
J. M. Hipple, engineer in charge, industrial division, engineering department.
F. I. Hiss, power division, engineering department.
William Hoopes, electrical engineer, Aluminum Company of America, New Kensington, Pa.
W. G. Houston, formerly, railway division, engineering department; now, assistant engineer, Hydro-Electric Commission of Canada.
R. P. Jackson, detail and supply division, engineering department.
O. S. Jenning, detail and supply division, engineering department.
C. N. Johnson, dynamo test.
A. T. Kasley, assistant to chief engineer, Westinghouse Machine Co.
H. C. Kendall, electrical department, University of Illinois.
B. G. Lamme, chief engineer.
A. C. Lanier, industrial division, engineering department.
E. E. Lehr, industrial division, engineering department.
P. M. Lincoln, general engineer, engineering department.
W. M. McConahey, engineer in charge, transformer division, engineering department.
Paul MacGahan, detail and supply division, engineering department.
J. N. Mahoney, detail and supply division, engineering department.
J. E. Mateer, transformer division, engineering department.
H. N. Muller, superintendent of distribution, Allegheny Co. Lt. Co.
H. C. Nagle, detail and supply division, engineering department.
F. D. Newbury, engineer in charge, power division, engineering department.
E. M. Olin, assistant superintendent, in charge of testing department.
H. W. Peck, assistant electrical engineer, Rochester Ry. & Lt. Co.
J. F. Peters, transformer division, engineering department.
K. C. Randall, engineer in charge, switchboard division, engineering department.
A. Reisfar, Hartley-Rose Belting Company, Pittsburg, Pa.
H. G. Reist, induction motor engineering department, G. E. Co.
H. Rodman, formerly, storage battery department, Westinghouse Machine Company; now, manager Rodman Chemical Co.
C. H. Sanderson, switchboard division, engineering department.
H. M. Scheibe, detail and supply division, engineering department.
R. A. Schmidt, general engineer, engineering department.
C. E. Skinner, engineer in charge, research division, engineering department.
C. H. Smith, engineer, executive department, Electric Company.
R. A. L. Snyder, plant engineer, C. D. & P. Tel. Co., Pittsburgh.
Nicholas Stahl, in charge of general contract division, railway and lighting sales department.
C. W. Starker, industrial division, engineering department.
C. E. Stephens, detail and supply division, engineering department.
E. C. Stone, engineering department, Allegheny Co. Lt. Co., Pittsburgh, Pa.
N. W. Storer, engineer in charge, railway division, engineering department.
W. Sykes, general engineer, engineering department.
C. L. Taylor, chief engineer, Morgan Engineering Company, Alliance, Ohio.
H. B. Taylor, detail and supply division, engineering department.
F. Thornton, detail and supply division, engineering department.
A. A. Tirrill, formerly, president, Tirrill Manufacturing Company, Athens, Pa.; now, detail and supply division, engineering department.
E. B. Tuttle, electrical engineer, C. D. & P. Tel. Co., Pittsburg.
Theo. Varney, industrial division, engineering department.
C. A. M. Weber, industrial division, engineering department.
W. R. Woodward, transformer division, engineering department.
F. E. Wynne, general engineer, engineering deypartment.
J. L. Yardley, power division, engineering department.

Supplement to THE ELECTRIC JOURNAL *for January, 1912.*

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PUBLISHED BY
THE ELECTRIC JOURNAL
PITTSBURGH, PA.

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(4) Approximate practical diagram; (5) experimental determination of inductive resistance of a transformer; (6) Kapp's diagram for pre-determination of drop and regulation; (7) diagram of auto-transformer. Explanation; diagrams; examples. D-8, W-2200. Vol. I, p. 410, Aug., '04.

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